Validity Report

Hearing Guidelines for the Selection of Entry Level Juvenile Corrections Officers

Local Juvenile Detention Facilities

March 2013

BOARD OF STATE AND COMMUNITY CORRECTIONS

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The Standards and Training for Corrections Program

The Standards and Training for Corrections (STC) Program is a division of the Board of State and Community Corrections (BSCC). The role of the STC Program in developing selection guidelines for local corrections personnel is set forth in Section 6035 of the California Penal Code. This law mandates the STC Program to develop, approve, and monitor selection and training guidelines for Juvenile Corrections Officers who work in locally operated juvenile detention facilities throughout California.

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EXECUTIVE SUMMARY

This report describes research conducted by the Board of State and Community Corrections to establish a hearing guideline for the selection of Juvenile Corrections Officers who work in local juvenile detention facilities operated by county probation departments throughout California.

The guideline emanating from this research applies to entry-level applicants for the Juvenile Corrections Officer position. Individuals in this position are responsible for the care, custody and control of 8500 juveniles detained in local juvenile detention facilities (October 31, 2011).

The research described in this report shows that these Juvenile Corrections Officers require a high degree of physical and sensory abilities to effectively perform their job. This research focused on the hearing abilities officers need to perform hearing-critical job functions. Hearing-critical job functions are those functions where hearing is absolutely essential, and no other sense modality or behavioral adaptation can be used to supplement hearing to perform the function.

Public protection and personal safety issues are significant for this position. Juvenile Corrections Officers are required to react and respond appropriately in time-sensitive situations. They must stop juveniles from injuring themselves or others, prevent escape, and respond to other emergencies. Officers are at risk of assault. The inability to fully engage in a critical and potentially life-threatening situation based on an inability to hear could set in motion a series of events that could have substantial negative consequences.

Research Elements

To determine the hearing-critical job functions that Juvenile Corrections Officers perform and to establish a hearing guideline for the hiring decisions, the Board of State and Community Corrections conducted research that comprised several steps and consisted of the following elements:

- Identification of the hearing-critical job functions Juvenile Corrections Officers perform;
- Determination of hearing abilities important in the performance of these functions (e.g., speech communication, sound detection and recognition, sound localization, etc.);
- Assessment of the impact of the sound environment, especially background noise levels, on the performance of these functions; and,

- Selection of valid and reliable screening tests and protocols to predict the necessary hearing abilities.

Research Approach

The research described in this report incorporated scientific advances in research methods related to hearing abilities to produce a guideline supported by strong empirical evidence. The research team utilized advanced, standardized statistical methods for analyzing workplace noise environments to determine their impact on hearing-critical job functions. This process incorporated recent methods to test hearing ability, especially as they relate to speech communication in quiet and noisy environments.

Highlights of Findings

The report describes the entire set of research procedures conducted to establish a recommended screening guideline. Highlights from the research are as follows:

- Juvenile Corrections Officers must rely on effective speech communication to perform hearing-critical job functions such as responding to a variety of disturbances and emergencies, communicating orally with juvenile detainees or other Juvenile Corrections Officers, and coordinating movements with other officers.
- Speech communication is a frequently used and demanding job function in the detention environment.
- Over half the cues for detecting incidents and emergencies involve hearing.
- Hearing-critical job functions are performed during all shifts.
- Background noise levels in the majority of local juvenile detention facilities can reach levels (or average) between 65 dB(A) and 80 dB(A). This is comparable to the noise levels in a noisy restaurant.
- Because of the noise levels occurring in the juvenile detention facilities during a routine day, using a normal voice level will result in less than perfect understanding of speech communication.
- Even a 15% reduction in effective speech communication can have substantial adverse consequences because effective communication is already made difficult by background noise levels in the juvenile detention environment.

Recommended Screening Guideline and Testing Protocol

Given that speech communication is so important in juvenile detention settings, the best way to assess functional hearing is to measure speech communication capability. Measures of speech recognition in noise are the best predictors of functional hearing abilities needed by Juvenile Corrections Officers. The new guideline is based on measures of speech recognition in quiet as well as in background noise levels that are representative of the Juvenile Corrections Officer's workplace.

The most appropriate and valid test to evaluate the functional hearing ability for the position is to measure the applicant's ability to understand speech in noise. The Hearing in Noise Test (HINT) is recommended for this purpose. Using the HINT, the screening criterion in quiet is 27 dB (A) or less. In noise of 65 dB(A), the screening criterion is 61 dB(A) or less, corresponding to a signal/noise ratio of -4 dB or lower.

Role of Standards and Training for Corrections

The Standards and Training for Corrections (STC) Program is operated by the Board of State and Community Corrections to develop and maintain guidelines for the selection and training of Juvenile Corrections Officers who work in juvenile halls and camps operated by county probation departments throughout California. The STC Program conducts job analyses, validation studies and related research to produce job-relevant guidelines for local hiring decisions and training programs. Participation in the STC Program is voluntary.

Local Juvenile Detention Facilities - Overview

All 58 California probation departments participate in the STC Program; of those county agencies, 52 counties operate juvenile detention facilities. Probation departments employ approximately 7100 Juvenile Corrections Officers to provide care, custody and control of juveniles housed in juvenile halls and camps.

As of October 31, 2011, there were 113 local juvenile detention facilities as defined by Title 15 of the California Code of Regulations (CCR). These facilities house juveniles up to the age of 18. The majority of juvenile detention facilities are secure facilities; a small number of facilities are set in rural areas with no security other than staff and location.

Based on Juvenile Detention Surveys compiled by the Board of State and Community Corrections, a one-day "snapshot" of the composition of the juvenile detainee population is as follows:

- Approximately 8,500 juveniles are housed in juvenile detention facilities throughout the state
- Eighty-one percent (81%) of the juveniles are between the ages of fifteen (15) to seventeen (17)
- Approximately 88% are males, 12% are females
- Of those juveniles, approximately 74% are charged with felonies; 26% are charged with misdemeanors

Juvenile Corrections Officers interact almost constantly with the juveniles during their detention as part of maintaining security and to assist in the rehabilitation process. Juvenile Corrections Officers also must handle a variety of behavioral issues juveniles present in these facilities. For example, in 2010 there were 316 suicide attempts (no completed suicides) and 282 assaults by juveniles on staff (Board of State and Community Corrections Juvenile Detention Survey).

The Juvenile Corrections Officer Position

Position Titles

For the purposes of this report, the title Juvenile Corrections Officer is used to describe those officers who work in a local juvenile detention facility and are responsible for the care, custody and control of juveniles. Titles for this position vary among jurisdictions throughout the state and include the following:

- Juvenile Counselor
- Group Supervisor
- Juvenile Detention Officer
- Group Counselor
- Probation Assistant

Regardless of the title used by the local agency, the position studied in this research is that of a line officer working in a juvenile detention facility. The majority of these officers perform similar functions even though the size or location of the facility or the officer's specific assignment may vary.

General Responsibilities

General areas of duties that Juvenile Corrections Officers perform include the following:

- Receiving and releasing juveniles
- Escorting and transporting detainees
- Record-keeping and report writing
- Supervising detainees
- Supervising non-detainee movement and visitors
- Searching and securing the facility
- Searching juveniles
- Communicating with juveniles, other Juvenile Corrections Officers, visitors and non-custodial personnel
- Performing physically demanding tasks such as running, subduing juveniles, and self-defense

GOAL OF RESEARCH: ENTRY-LEVEL SELECTION GUIDELINE

The hearing guideline resulting from this research pertains to the hiring of entry-level applicants for the local Juvenile Corrections Officer position. Approximately 8,500 people apply for this position annually.

The hearing guideline that emanates from the research described in this report is based on the minimum performance levels found to be applicable across the full range of agencies participating in the STC Program. Whether meeting this guideline indicates an applicant's ability to meet a specific agency's local performance requirements depends on how that agency's local circumstances compare to the statewide performance dimensions as identified through this research.

In circumstances where local performance requirements are the same as the statewide performance requirements and an applicant is unable to meet the guideline, the hiring agency should evaluate the applicant on a case-by-case basis. An applicant should not be automatically disqualified from placement in the Juvenile Corrections Officer position for failure to meet the recommended guideline. The employing agency should conduct a case-by-case evaluation and determine whether the agency is obligated under applicable statutes and/or regulations to make reasonable accommodation for an applicant who may be unable to meet the recommended hearing guideline.

Research Strategy

The strategy to develop valid applicant screening measures consisted of four major elements:

1) Identification of hearing-critical job functions and the hearing abilities needed to perform these functions;
2) Assessment of the noise levels in the environment where these functions are performed;
3) Analysis of the noise levels and the likelihood of ability to perform hearing-critical job functions in these noise levels; and,
4) Selection of valid and reliable screening tests and protocols to predict the necessary hearing abilities.

The research strategy was designed as a sequence of steps, with each step establishing the foundation for the next. This approach linked the important hearing-critical job functions to the screening measures and screening criteria of hearing ability.

The Research Focus

The research process involved a decision about which hearing ability to focus on (sound detection, speech communication, sound localization, etc.). From the initial stages of the research, it became clear that speech communication was an important functional hearing ability for Juvenile Corrections Officers. It was also evident that this speech communication at times took place in noisy environments. These observations refined the research approach to determine if the ability to communicate with speech in noisy environments is a sufficiently important hearing ability to warrant use as a screening measure. If so, the selection of the guideline for hearing could focus primarily on speech communication.

There were several advantages to adopting such a focus. One advantage was the availability of standardized ways to quantify speech communication ability. Another advantage was that speech communication in quiet and noise is perhaps the most demanding and challenging of all functional hearing abilities. If applicants can hear well enough to communicate effectively with speech in quiet and noise, then it is reasonable to assume they can also hear non-speech sounds in these environments.

The remainder of this section summarizes the specific research steps, emphasizing the link between the hearing-critical job functions and the screening criteria.

Summary of Research Steps

Hearing-Critical Job Functions

The research began with a review of existing job analyses for the Juvenile Corrections Officer position. This review provided the context for subsequent steps that focused on specific hearing-critical job functions.

Research staff then collected written incident reports from a representative sample of juvenile detention facilities throughout the state. Incident reports document unusual or unlawful activities and events that occur within a detention facility. These incident reports were analyzed to identify important hearing-critical job functions Juvenile Corrections Officers perform when responding to the incidents.

Following the analysis of the incident reports, the research team conducted semi-structured interviews with experienced Juvenile Corrections Officers who served as subject matter experts (SMEs) to further identify hearing-critical job functions they performed during routine days and during emergencies.

The SMEs also identified the locations within the facilities and the times throughout the day where hearing-critical job functions involving speech communication are most likely to take place. This information served as an important basis for planning the visits to the juvenile detention facilities so research staff could observe hearing-critical job functions being performed in the pertinent locations and at the appropriate times to measure and record background noise environments for later analyses.

Research staff synthesized the evidence gathered in the analysis of the incident reports and interview data. Findings from these steps repeatedly and consistently underscored the importance of accurate and effective speech communication in the performance of many hearing-critical job functions. Having identified the importance of speech communication in noise as a major functional hearing ability, the subsequent research focused primarily on this ability.

Background Noise Measurements

To assess the conditions under which Juvenile Corrections Officers perform hearing-critical job functions, research staff visited a representative sample of juvenile detention facilities throughout the state. The primary aspects used in selection of the sample were the number of detainees, geographical regions within the state, security levels of housing within each facility, and gender of the detainees.

The research team made high quality calibrated digital sound recordings several minutes in length at each sampled facility at specified times and locations. The research team also maintained detailed logs describing the conditions for each recording.

Analysis of Background Noise Measurements

Each noise recording was analyzed using standardized, validated procedures for measuring speech intelligibility.

The research team assigned weights to the noise analyses for each location in the juvenile detention facilities where hearing-critical job functions were performed. Using standardized calculations to estimate the likelihood of accurate and effective speech communication in each background noise environment, research staff incorporated reduced audibility estimates into estimates of the likelihood of effective speech communications.

Screening Guideline

The research evidence indicated that each aspect of the hearing guideline, the screening materials, the protocol, and the criteria, should be based on measures of the ability to communicate with speech.

Two different hearing screening criteria are recommended. The first is based on the Speech Reception Threshold (SRT) in quiet as measured with the Hearing in Noise Test (HINT). This criterion is specified to ensure that applicants with reduced audibility caused by hearing impairment can hear and understand soft or whispered speech.

The second is based on a composite of three SRTs measured in noise. This criterion is recommended to ensure that applicants with increased distortion caused by hearing impairment can hear and understand speech in the noise environments where Juvenile Corrections Officers routinely perform hearing-critical job functions.

STEP 1: EXISTING JOB ANALYSIS REVIEW

The first phase of the research identified hearing-critical job functions. The first step of this phase consisted of a review of the most recent job analysis questionnaires completed by incumbent line Juvenile Corrections Officers and their immediate supervisors.

Background and Rationale

Research staff reviewed the results of the 2002 job analysis conducted by the Board of State and Community Corrections. This job analysis focused on line officers who had completed their probationary period, worked independently, and performed duties typical of the majority of Juvenile Corrections Officers.

The job analysis identified tasks performed and equipment used by Juvenile Corrections Officers who worked in various juvenile detention facilities throughout the state. These tasks and equipment items were endorsed by both supervisors and line officers as being frequently performed and used as well as being important to the job.

Methodology

As the initial step in the identification of hearing-critical job functions, research staff reviewed the job analysis findings. This involved examining the list of tasks and equipment items to determine those which had a hearing-critical component. Although the term "hearing" was not often used in the description of each task, the research team was able to identify hearing-critical tasks from words such as "listen", "communicate orally", and "monitor". Research staff were also able to identify equipment items with hearing ability as a key component, such as an intercom, telephone or radio.

Results

This phase of the research revealed that a large number of tasks required Juvenile Corrections Officers to hear on the job. Most of these tasks indicated that officers need to hear and understand spoken words as well as non-speech sounds.

The following list is a sample of hearing-related tasks that were rated in the job analysis as being frequently performed and critical to the job:

Supervising Individual Juveniles

- Communicate orally with juveniles
- Respond to juveniles' verbal questions or requests
- Conduct on-the-spot crisis counseling

Supervising Groups of Juveniles

- Prevent unauthorized detainee communication
- Supervise and monitor behavior of juveniles in exercise areas
- Observe/monitor attitudes and conduct of juveniles, watching for signs of potential disturbance, medical or psychiatric needs, or signs of drug or alcohol use
- Anticipate, monitor and intervene in disputes between juveniles (before a fight occurs)
- Notice subtle changes in group juvenile behavior patterns (e.g., noise levels, juvenile interactions, etc).

Communicating with Co-Workers and Supervisors

- Communicate orally with other Juvenile Corrections Officers regarding facility operations
- Respond to and dispatch help for emergencies
- Follow oral instructions from supervisors and others
- Attend staff meetings and confer with supervisors concerning facility operations

Other Hearing-Related Tasks

- Answer incoming phone calls, provide information (e.g., about facility policies, court procedures, individual juveniles, etc), route calls and take messages
- Listen for unusual sounds or sounds that may indicate illegal activity or disturbance (e.g., whispering, scuffling, sudden quiet or change in noise level, horn honking, rattling of chain link fence)

Discussion

The review of the job analysis provided information about major areas of the Juvenile Corrections Officers responsibilities as well as allowed research staff to identify several tasks and equipment items with a hearing component. This review also provided a foundation for subsequent steps in the research, especially those steps that involved analysis of incident reports and interviews with Juvenile Corrections Officers.

Step 2: Incident Report Analysis

The second step in the research process was to analyze hearing-critical job functions from incident reports obtained from local juvenile detention facilities throughout the state.

Background and Rationale

An analysis of incident reports can, at least indirectly and often directly, reveal those hearing-critical job functions that were performed in response to incidents and the interventions needed to resolve them.

Incident reports are completed by the Juvenile Corrections Officer each time anything out of the ordinary occurs during their shift. This includes rule violations such as fights between detainees, assaults on Juvenile Corrections Officers and other staff, detainees behaving in a disruptive or unusual manner, or possession of contraband. Incident reports are also completed for any medical emergencies or suicide attempts. Three examples of incident reports included in Figure 1 below illustrate what is typically included in a report. These examples are presented with the names of individuals replaced with uppercase letters to preserve anonymity.

Methodology

The research team requested incident reports from facilities that represented the diversity of geographic locations and facility sizes across the entire state. Facilities were asked to supply at least 30 incident reports representing all the shifts and covering as wide a range of types of incidents as possible (without regard to any hearing abilities or functions required of their officers).

It was anticipated that the incident reports would reveal the following types of information:

- How the incident was detected
- The location of the incident
- The time of the incident
- What happened during the incident
- How the incident was resolved

This was the starting point to develop a set of categories and the elements within each category that would represent the content of the incident reports. Once several hundred incident reports were received, research staff carefully reviewed them and developed a preliminary version of the coding schema. This preliminary version was modified as necessary and applied to another set of incident reports. This iterative process continued until a final coding schema emerged.

Example #1: **Attempted assault on staff:** "On 4/23/11 at approximately 20:24 while on duty on unit 4C, a Code Red was called on the unit. I was positioned in front of the unit television when I hear PCO T yell "Watch out!" I swiveled my head slightly to the right and saw Minor R move swiftly at me. He attempted to either knock me down or tackle me, but was only able to bounce off my body. I recovered as he was facing me with his back to the dayroom table nearest the unit telephones. Fearing that he would attempt to attack me again, I grabbed him in a bear hug like hold and took him to the ground. Immediately, PCO T assisted me in holding the minor in a high risk handcuffed position, holding his right side while I had the left side. PCO L gave minor R several OC warnings until he complied. The minor continued to struggle while PCO M applied handcuffs on him. After he was handcuffed and secured he was escorted by PCO T and myself to holding."

Example #2: **Attempted Suicide/Medical Emergency:** "On October 1, 2009, I Deputy Juvenile Corrections Officer J worked my assigned shift in ISU from 6 am to 10 pm. At approximately 8:33 pm, I …heard DCJO R yell from someplace down the hallway 'Code, Medical Emergency. Hurry, medical emergency.' I ran towards the door, I yelled to the group that was sitting in the day area, 'Heads down, put your heads down.' DJCO R was standing at Minor F's door and was attempting to open it. The door was opened by DJCO R and we both entered. Minor F was lying on his back with his head to the side. Minor F had a bed sheet wrapped round his neck and had twisted it tight several times. The bed sheet went tight from his neck to his feet, where he had tied the two ends to his legs. Minor F was completely motionless and did not respond to any of my or DCJO R's instructions. I immediately grabbed Minor F's head and tried to push it through the sheet. The sheet was twisted tight and it took for DJCO R to lift Minor F's knees to his chest area for the sheet to be loose. With DJCO R holding Minor F's knees up from the bed, I was able to pull the sheet apart and push his head through the loop. I placed two of my fingers on his neck to feel for a pulse, at this moment a pulse was not detected. Minor F was still motionless and unresponsive. I began to shake Minor F's head and shoulders. I heard DJCO R say that Minor's hands and arms were cold to the touch. I placed two of my fingers on Minor F's neck, and this time detected a pulse. I began to shake Minor F's face and tap on his cheeks with my hands for a response. At this time, Minor F began to shake lightly as if he were having a small seizure. His arms, legs, and head began to shake while taking a breath. Once it was obvious that he was breathing, I grabbed his hand and squeezed it to show him someone was there. About now, other responding staff from adjoining units and ISU were present. Medical was also present and was in the room to take over care of Minor F. I stepped out of the room and stood in the hallway. I could hear medical taking over and knew Minor F was ok."

Example #3: **Suicide Threat/Hallucinations**: "On 7/7/2009, at approximately 1940 hours, Minor T was banging on the door and wall of her room. This action was causing the other minors to yell out their doors telling her to stop. I was passing out a snack at this time and I opened Minor T's door and asked her if she wanted her snack. Minor T responded with '####you'. I asked Minor T why she was banging and she told me because of the voices in her head. I told Minor T that if she continued to bang, yell and disturb the other minors in the unit, I would have to make her stop. I told her she might be sprayed or moved to A-Unit. She said that she would stop banging, but she would not stop yelling. I asked Minor T if she had taken her medication and she stated, 'No'. She also told me that she was not going to take her medication tonight because it does not silence the voices in her head. I asked her one more time if she wanted her medication and again she said, 'No'. At 2000 hours, I… went to Minor T's room to request that she take her medication. I counseled Minor T to no avail. While I counseled the minor she advised that I might want to put her in a gown. She showed me some light scratches on the inside of her forearm. She said her voices are telling her to kill herself and to hurt the people that make fun of her. She said she thinks she should listen to her voices and agrees that it would be a good idea to kill herself. Minor T stated that she would try to kill herself while she is in juvenile hall, but if she were unsuccessful she would make an attempt while she is out of custody. I had JCO L watch the minor while I made contact with Doctor S. Doctor S advised that the minor should be placed in a safety gown with 15-minute room checks. I had JCO K escort Minor T to the intake shower where she was placed in a safety gown. The minor was then moved to B-Unit room #1 for observation."

Figure 1: Examples of Incident Reports

Coding of the Incident Reports

The final set of categories developed for the coding schema was as follows:

- Location of Incident
- Types of Incidents
- Time of Occurrence
- Sensory Cues
- Type of Sound Cue: Speech or Non-speech
- Visibility of Sound Source

Each category consisted of multiple elements that were coded and then tabulated in a frequency count. The elements that comprised each of the categories are listed below.

Location of Incidents

One category included in the coding system was the location where an incident took place. Based on the review of the incident reports, the research team determined that incidents in the following locations were documented in the reports:

- Housing
- Classroom
- Outside Recreation (Yard)
- Dining Hall
- Receiving
- Inside Recreation (Gym)
- Detainee Movement
- Kitchen
- Visiting Area
- Medical
- Control Booth

Types of Incidents

Another category in the coding system was the type of incident that had occurred. The actual incident itself was categorized into one of the following seven elements:

- *Contraband*: Weapons, drugs, or any other unauthorized items (e.g., an extra blanket, extra socks, etc.)
- *Medical Intervention*: Death, bleeding, collapse, seizure, physical trauma, unintentional self-injury; need for First Aid, CPR
- *Non-Assaultive/Oppositional Behavior*: Active verbal/vocal interaction, oppositional behavior, not following instructions, banging on walls with attempts to be

disruptive, and non-assaultive threatening behaviors such as fist clenching. Recounts of vocal/verbal events, summaries, or third party accounts not considered here

- *Physical Assault/Battery/Altercation One-on-One (2 people)*: Physical altercations, assaults, or battery; does not include physical threats such as fist clenching, or injuries against self
- *Physical Assault/Battery/Altercation Group (3+ People)*: Physical altercations, assaults, or battery among a group of three or more individuals; does not include physical threats such as fist clenching, or injuries against self
- *Suicide, Suicide Threat, Suicide Attempt/Self-Injury*: Suicide, suicide threats, attempts or other instance of self-injury; banging head on wall or floor, punching/kicking walls or other inanimate objects (with intent to harm oneself). Unintentional self-injury is not considered here
- *Unusual/Abhorrent Behavior*: Crying, indecent exposure, hallucinations, intoxication, altered emotional states, etc.; threats of suicide not included in this category

Time of Occurrence

The research team examined the time the incident occurred. These times were then grouped into three time periods or "watches":

- *Watch One* 10 pm until 6 am
- *Watch Two* 6 am until 2 pm
- *Watch Three* 2 pm until 10 pm

Sensory Cues

The research team then examined how the incident was initially detected by the reporting officer.

Each incident was examined to see if the reporting officer initially detected it by using only hearing, by using only vision, or by using both vision and hearing.

- *Vision only*: Officer detected the incident based on a visual cue
- *Hearing only*: Officer detected the incident based on an audible cue
- *Both vision and hearing*: Officer detected the incident based on simultaneous visual and audible cues

Type of Sound Cue: Speech or Non-Speech

If it was determined that an incident was detected with an audible cue, the research team looked at the next category of the coding system to determine if the cue was speech or non-speech. If an incident was detected by a visual only cue, it was not included in this category.

- *Speech*: Verbal communication
- *Non-speech*: All other sources of sound, excluding verbal communication

Visibility of Sound Source

The next category of the incident reports that was coded by the research team was the visibility of the sound source. This category dealt with only the incidents that were coded as having an audible cue; the audible cue was coded as being either visible or not visible. If the reporting officer was alerted to the incident by a visual cue, it was excluded from this category.

- *Visible*: Officer was able to see the source of the sound
- *Not visible*: Officer was not able to see the source of the sound

Results

Incident Reports Received

The research team collected 946 incident reports from 27 representative facilities throughout the state, encompassing a range of facility types and sizes. A list of participating facilities is provided in Appendix I.

Each facility provided a different number of incident reports, ranging from as few as one to as many as 117. Because of this range, it was determined that to be represented in the data analysis a facility needed to have sent a minimum of five incident reports. A maximum of 15 incident reports from each facility were processed; if a facility sent more than 15 reports research staff randomly selected a maximum of 15 for use in this research.

Weighting Process

The strategy for including incident reports in the data analysis resulted in facilities contributing different numbers of reports. To deal with this issue in the processing of the data, the research team implemented a weighting system so that all of the facilities could contribute equally to the compilation of the tabulated results. The general processes that were used to implement the weighting strategy are outlined below.

Conversion of Frequencies to Percentages by Facility

Research staff tabulated the frequency of occurrence for each element within each coded category. These frequencies were then transformed into a percentage of the total elements within each category for each facility. For example, if a facility had x number of incidents occurring in housing, y number of incidents occurring in booking, and z number of incidents occurring in the dining hall, research staff computed the total number of incidents across all locations for that facility. The percentage value for housing, booking, and dining hall represented the proportion of x, y, and z with respect to the total. These percentages rather than the raw frequency counts were then used as the data for subsequent data compilation. This process was carried out for each of the six coding categories for each facility.

Accounting for Rated Capacity of Facilities

Rated Capacity describes the number of occupants that can be housed in a juvenile facility based on compliance with all applicable standards (Title 15, California Code of Regulations). The 27 facilities were divided into three groupings based on their rated capacity:

- Nine (9) facilities had a rated capacity of less than sixty (60).
- Twelve (12) facilities had a rated capacity between sixty (60) and two hundred and forty (240).
- Six (6) facilities had a rated capacity over two hundred and forty (240).

Weighting by Rated Capacity

Once the percentages were found for each element within each coding category for a facility, these percentages were averaged with the other facilities within their rated capacity group to provide a single percentage for each element within each category for the rated capacity group.

After computing the one percentage for each element within each category for each rated capacity group, the three rated capacity groups were then averaged. To project the percentages to the state as a whole, the proportion of facilities falling into the rated capacity groupings used here was taken into account. Across the state, 42.6% of facilities have a rated capacity of less than 60, 47.8% of facilities have a rated capacity of 60 to 240, and 9.6% of facilities have a rated capacity of over 240. Thus for each element within each category, the three percentages from capacity groups less than 60, between 60 and 240, and over 240 were combined to produce a weighted average using weights of .426, .478, and .096, respectively, for the three capacity groups. These weighted averages are presented in the tables below.

Location of Incidents

Table 1 displays the areas in which incidents occurred. "Location" contains the names of the locations where incidents occurred within each facility. The number of incidents for each location was compiled over the full set of 402 reports. These counts are presented in Table 1. However, it is important to note that in the weighting process, the raw counts were immediately transformed to percentages. Thus, for example, the number of occurrences of housing for Facility A was converted to the percentage of reports indicating that an incident had taken place in housing. That percentage was averaged with the other housing percentages for all of the other facilities in its rated capacity group to yield a single housing percentage. This single percentage was subsequently included with the other two housing percentages from each of the other rated capacity groups to form a weighted average percentage of all three groups. The weighted average percentage, shown in the third column of Table 1, thus represents a composite summary of the sample of facilities.

Because of the transformation of frequency counts to percentages that were used to compute the weighted average, it should be noted that the weighted average percentage may not exactly match the proportion of the number of incidents for the elements (locations). For example, the 262 incidents in housing represent 65.17% of the total 402 incidents, but the weighted average percentage for housing is 64.41%. Nonetheless, both ways of viewing the tabulation reveal that the majority of the documented incidents occurred in housing.

Table 1: Location of Incidents

Location	# of Incidents	Weighted Average Percentage
Housing	262	64.41%
Outside Recreation (Yard)	41	10.92%
Classroom	42	8.64%
Receiving	19	5.94%
Dining Hall	15	3.89%
Inside Recreation (Gym)	9	3.21%
Detainee Movement	9	2.69%
Visiting Area	2	0.73%
Control Booth	1	0.66%
Kitchen	2	0.39%
Medical	0	0.00%
TOTAL	402	100.00%

Note. Medical is included in Table 1 with a frequency of zero. Subsequent research steps identified this location as one where Juvenile Corrections Officers perform hearing-critical tasks. Therefore, to achieve consistency throughout this report, research staff created one standard list of locations.

Types of Incidents

Table 1 displays the areas in which incidents occurred. "Incident Report Type" contains the types of incidents occurring in the facilities. The number of incidents for each type is compiled over the full set of 402 reports as reported in Table 2. Table 2 also shows the weighted average percentage computed as previously described. Once again, the raw frequency counts were transformed to percentages as described above. Therefore, they are not necessarily interchangeable with each other but still allow the same conclusions to be drawn. Generally, incidents involving non-assaultive/oppositional behavior were most prevalent, followed by physical assault/battery/altercation one-on-one. The fewest incidents were reported under the unusual/abhorrent behavior category.

Table 2: Types of Incidents

Incident Report Type	# of Incidents	Weighted Average Percentage
Non-Assaultive/Oppositional Behavior	188	46.77%
Physical Assault/Battery/Altercation One-on-one	108	26.48%
Contraband	40	11.24%
Medical Intervention	23	5.47%
Suicide, Suicide Threat, Suicide Attempt/Self-Injury	22	4.81%
Physical Assault/Battery/Altercation Group	15	3.54%
Unusual/Abhorrent Behavior	6	1.68%
TOTAL	402	100.00%

Time of Occurrence

Table 3 displays the times when the incidents occurred. "Shift" contains the watches when incidents occurred. The number of incidents for each watch is compiled over the full set of 402 reports. Table 3 also displays the weighted average percentage computed as previously described. Although the raw frequencies and the weighted average percentages are not completely interchangeable, it can be seen from the table that almost all of the incidents occurred during the second and third watches.

Table 3: Time of Occurrence

Shift	# of Incidents	Weighted Average Percentage
Watch One (10 pm – 6 am)	16	4.63%
Watch Two (6 am – 2 pm)	187	44.95%
Watch Three (2 pm – 10 pm)	198	50.31%
Not Reported	1	0.11%
TOTAL	402	100.0%

Sensory Cues

Table 4 displays the sensory cue used by the reporting officer to alert him/her that an incident was taking place. The number of incidents for each cue is compiled over a smaller subset of 250 reports because approximately 40% of the incidents that indicated vision was the only sensory cue used in incident detection were excluded from this compilation. Table 4 also displays the weighted average percentage. As can be seen from the table, slightly less than two-thirds of the incidents (250/402 = .62) involved hearing as a critical component. Of those incidents involving hearing, about half involved both vision and hearing and the other half involved hearing only.

Table 4: Sensory Cues for Incidents

Sensory Cue	# of Incidents	Weighted Average Percentage
Both vision and hearing	131	54.02%
Hearing only	119	45.98%
TOTAL	250	100%

Note. The total number of incident reports in the table differs from the total number of incident reports collected (402) in that 152 (or 38%) of the incidents were detected using only vision; therefore, hearing was not a critical component.

Type of Sound Cue: Speech or Non-Speech

Table 5 displays the type of sound that alerted the officer to an incident. "Type of Alert" indicates the number of incidents to which an officer was alerted by speech or non-speech sounds. The number of incidents for each type of alert is compiled over a smaller subset of 250 reports. As was described above, about 40 percent of the incidents indicated vision was the only sensory cue used in incident detection and these were excluded from this compilation. Table 5 also displays the weighted average percentage. As can be seen from the table, slightly less than two-thirds of the incidents (250/402 = .62) involved hearing as a critical component. Of those incidents involving hearing, the vast majority of the alerts involved speech communication.

Table 5: Type of Sound Cue

Type of Alert	# of Incidents	Weighted Average Percentage
Speech	211	84.37%
Non-speech	39	15.63%
TOTAL	250	100%

Note. The total number of incident reports in the table differs from the total number of incident reports collected (402) in that 152 (or 38%) of the incidents were detected by a visual only alert; therefore, hearing was not a critical component.

Visibility of Sound Source

Table 6 shows the type of sound that alerted the officer to an incident as visible or not. "Visibility" indicates the number of incidents to which an officer was alerted by a visible or not visible sound source. The number of incidents for each type of alert is compiled over a smaller subset of 250 reports. Again, about 40 percent of the incidents indicated vision was the only sensory cue used in incident detection and these were excluded from this compilation. Table 6 also displays the weighted average percentage. As can be seen from the table, slightly less than two-thirds of the incidents (250/402 = .62) involved hearing as a critical component. Of those incidents involving hearing, the majority of the alerts involved a visible sound source.

Table 6: Visibility of Sound Source

Visibility	# of Incidents	Weighted Percentage
Sound Source Visible	192	79.78%
Sound Source Not visible	58	20.22%
TOTAL	250	100.00%

Note. The total number of incident reports in the table differs from the total number of incident reports collected (402) in that 152 (or 38%) of the incidents were detected by a visual only alert; therefore, hearing was not a critical component.

Discussion

From the 402 incident reports that were analyzed, over 60% of the incidents required the Juvenile Corrections Officers to detect and respond to the incidents using their hearing abilities. When hearing was the critical component (as opposed to vision) in alerting the Juvenile Corrections Officers to an incident, the majority of the audible cues were in the form of speech. This reinforces the importance of being able to detect and understand speech communication.

Step 3: Interviews with Juvenile Corrections Officers

The third step in the research process identified hearing-critical job functions through interviews with Juvenile Corrections Officers who served as subject matter experts (SMEs). These interviews consisted of two phases: the first phase entailed semi-structured interviews with panels of incumbent Juvenile Corrections Officers and their immediate supervisors; the second phase comprised informal, on-site interviews with officers and their supervisors.

Background and Rationale

Analysis of the incident reports conducted in Step 2 provided substantial detail about when and where incidents occurred. The interviews during Step 3 gathered more detail about the performance dimensions of the hearing-critical tasks.

For the panel interviews, the research team selected the commonly used method of semi-structured interviews (e.g., Guion, 1998) to examine the Juvenile Corrections Officer job as it relates to hearing. Research staff met with SMEs, experienced Juvenile Corrections Officers who have either performed the job for several years or who supervise them. Small groups of SMEs were interviewed together, which allowed each SME to enrich the information supplied by other SMEs. This method is not only time efficient, it also enables integration of SME responses (Brannick et al., 2007). Often, the group process allows information to surface that might not otherwise be obtained during individual interviews.

In contrast, the on-site interviews were less structured than those conducted during the panel interviews. The informal nature of the interviews enabled the research team to engage in individual dialogue about specific hearing-critical job functions and hearing challenges in the facilities. Additionally, the on-site interviews had the advantage of allowing research staff to directly observe the specific locations officers worked and the distances from sound sources.

Panel Interview Methodology

The research team assembled two panels of Juvenile Corrections Officers. Eight officers representing juvenile detention facilities from eight different counties were selected for these panels based on their extensive knowledge of the job. (Please see Appendix I for a list of facilities represented in the Panel Interviews.)

The SME panel meetings explored activities within facilities that involved hearing-critical job functions. The research team asked the SMEs a series of questions related to these functions to determine where and when they occurred and what they entailed. The SMEs responses and subsequent discussion provided details about each function and the hearing abilities used to perform the function.

The panel interview process was divided into two phases. The first phase focused on hearing-critical job functions that occur throughout a routine workday; that is, a composite of duties officers perform as part of their day when they are not responding to emergencies or incidents. The second phase addressed hearing-critical job functions that occur in response to emergencies or incidents at any time during a shift.

Hearing-Critical Job Functions During a Routine Day

Each SME was assigned a different four-hour time segment during the routine day. They were then asked to identify 5–6 hearing-related hearing job functions that a Juvenile Corrections Officer might perform during that time segment. They were encouraged to construct a mental composite to represent the activities during that time period. This process was repeated for each time segment to characterize the entire routine day. Once the day had been reconstructed in this manner, the panel analyzed each identified job function to determine the hearing abilities used in performing the function.

For speech communication activities, SMEs were asked to identify or describe:

- Vocal effort of the communication (whispered/softly spoken, normal, raised, shouted)
- The degree to which the message was understood
- Whether the speech could be repeated

For non-speech sounds, SMEs were asked to identify or describe:

- Whether the activity required detection, recognition, or localization
- The amplitude of the sound
- The characteristics of the sound (single burst, continuous, intermittent)

For all sounds, SMEs were asked to identify or describe:

- The distance of the Juvenile Corrections Officer from the sound source
- Whether the source was visible
- The level of the background noise
- The overall effort needed to hear the sound

The specific questions posed to the SMEs are reported in Appendix B. Two interview questions did not yield useful information: the degree to which a message was understood; and, the distance of officers from the sound source. SMEs had difficulty providing these estimate; therefore, no data for these questions are reported.

Hearing-Critical Job Functions During Incidents

After the review of a routine day, SMEs described incidents. Since incidents do not necessarily occur during a specific watch, the SMEs were simply asked to recall an incident they had experienced that involved hearing. Once the SMEs related such an event, they were asked when and where that incident had occurred, and whether the cue for the incident involved speech communication or other non-speech sounds. With this information in hand, the research team guided the SMEs through the same series of questions as those presented during routine day recollections.

Panel Interview Results

Research staff analyzed the results from the interviews by tabulating the frequencies of occurrence for each response category. Separate tabulations were made for speech and non-speech sounds and for the routine day and for incidents. These results are reported below.

Locations

Table 7 shows the percentages of time functional hearing abilities were used in the performance of hearing-critical job functions at the most commonly reported locations in the facility. Separate entries are given for a routine day and during responses to incidents.

The most common area for hearing-critical job functions was housing. Speech communication needed to be understood over 40% of the time during a routine day and incidents. Non-speech sounds needed to be heard almost 58% of the time during a routine day and over 40% of the time during incidents.

Table 7: Locations of Hearing-Critical Job Tasks

Areas where speech and non-speech functional hearing abilities were used to perform hearing-critical job functions during a routine day and during responses to incidents

Location	Speech		Non-Speech	
	Routine Day N=23	Incidents N=7[1]	Routine Day N=19	Incidents N=19*
Housing	43.5%	42.9%	57.9%	42.1%
Inside Recreation (Gym)	13.0%	14.3%	10.5%	15.8%
Classroom	8.7%		5.3%	5.3%
Outside Recreation (Yard)	8.7%			5.3%
Detainee Movement	8.7%			
Visiting Area	8.7%		5.3%	
Receiving	4.3%		10.5%	15.8%
Dining Hall	4.3%		5.3%	
Kitchen				
Medical		14.3%		5.3%
Control Booth				5.3%
Total	100%	71.5%	100%	94.9%

Note. One location is included in Table 7 without an entry: kitchen. Subsequent research steps identified this location as one where Juvenile Corrections Officers perform hearing-critical tasks. Therefore, to achieve consistency throughout this report, research staff created one standard table that encompassed all sources of information referring to location.

Other Results from Panel Interviews

The SMEs reported that during a routine day, many of the hearing-critical tasks require communication with speech. SMEs also noted that it is common for tasks to involve the detection and recognition of non-speech sounds.

During a routine day, the frequency of whispered/softly spoken, normal, and raised vocal effort was relatively equally distributed, while shouting occurred rarely, if at all. This contrasts with the vocal effort used during responses to incidents, where the majority of the time of the time Juvenile Corrections Officers used raised or shouted vocal effort.

The act of vocal repetition was more common during incidents, while during a routine day it was used for approximately only half of the time. Elevated levels of vocal effort and repetition were commonly needed to achieve effective communication with speech,

[1] SMEs recounted three incidents occurring in administrative building areas; thus, they could not be classified into any of the location areas listed in the table. They are therefore not included in Table 7 above. Because the sample size (Ns) of 7 and 19 include those three incidents, the totals do not sum to 100 percent. (Ns) of 7 and 19 include those three incidents, the totals do not sum to 100 percent.

particularly while performing hearing-critical job functions during the occurrence of incidents. (Please refer to Appendix C for a specific numerical breakdown of other SME Panel Results.)

SMEs estimated the background noise levels to be relatively equally distributed between quiet, medium, and loud during a routine day in which speech communication was necessary. During the occurrence of incidents, background noise levels were generally quiet for both speech communication and non-speech sounds. (Please refer to Appendix C for a numerical breakdown of other results from the SME Panel Interviews.)

When asked if the source of the sound was visible, the SMEs indicated that most of the time the source of sound or speech was not visible. This held true for both routine days and during incidents, therefore demonstrating the importance of hearing in detecting and responding to hearing-critical tasks during both routine day tasks and incidents.

During a routine day, the amount of effort to hear speech communication was relatively equally distributed among low, medium, and high levels of effort. During incidents, officers expended low amounts of effort about three-quarters of the time to hear both speech and non-speech sounds.

The SMEs described the hearing-critical job functions Juvenile Corrections Officers must perform to maintain safety and security. Many of these involved compelling examples of situations involving the need to hear. Three such examples are as follows:

- A juvenile yelling for help as she was going into labor
- Juveniles exchanging threats against each other through the vents
- A juvenile threatening to commit suicide from his room

Individual Interview Methodology

To supplement the SME Panel Interviews, research staff conducted individual interviews with 17 Juvenile Corrections Officers at the officers' respective detention facilities. The selection of the 17 facilities where interviews were conducted followed a stratified sampling plan that captured an approximately proportional representation of all local juvenile detention facilities throughout the state according to geographical region and rated capacity. In some jurisdictions, more than one facility was sampled if rated capacity differences were represented. (For a list of facilities that comprised the sample, please see Appendix I.)

All SMEs interviewed had several years experience on the job and were knowledgeable about the Juvenile Corrections Officer position as well as their facility. In the few cases where the SME had worked in other facilities or jurisdictions, the SME was asked to respond to the interview questions from the perspective of his/her current assignment. This focus preserved the sampling plan's proportional representation.

Research staff asked each SME to cite a total of six examples of hearing-critical job functions; three examples of hearing-critical sounds (such as alarms) and three examples of hearing-critical speech communication (such as responding to detainee's questions). Research staff gathered examples for both sounds and speech communications that occurred during routine days as well as during emergencies or incidents.

For examples of hearing-critical sounds, research staff asked the SMEs for estimates of the background noise level against which the sound was heard (quiet like an office, noisy like a busy restaurant, or somewhere in between). Further, research staff asked if the source of the sound was visible.

For examples of hearing-critical speech communication, research staff asked about the background noise level (as above), the visibility (as above) as well as whether there was an opportunity to repeat the speech communication without negative consequences occurring. Further, the SMEs were asked to describe the voice level of the speaker during these communications (whispered or softly spoken, normal, raised or shouted).

Additionally, research staff asked each SME to rate the importance of speech communication to the job of a Juvenile Corrections Officer (not important, somewhat important, or very important).

Individual Interview Results

The SMEs provided 101 examples of hearing-critical job functions. Examples included both hearing-critical sounds and speech communication. Examples are as follows:

- Radio transmissions (often needed to be repeated; sometimes heard incorrectly)
- Listening for unauthorized conversations between detainees
- Monitoring the tension among the group as reflected by conversation level (either too loud or too soft)
- Understanding a juvenile speaking in an agitated manner
- Hearing chairs and tables being moved abruptly (indicates fight in progress)

Categories of Examples

- *Sounds*: During a routine day, the SMEs reported most often hearing phones, intercoms, radios, and alarms, followed closely by juveniles pounding, throwing, hitting, and scraping objects. The third most common sound was hearing doors locking. During emergencies the most frequently heard sounds were juveniles pounding, throwing, hitting, and scraping objects, followed by physical altercations, intercoms, radios and alarms.

- *Speech Communication*: During a routine day, SMEs reported equal amount of time hearing each of the categories. During emergencies, the SMEs heard radio, intercom and phone communication almost half of the time, staff to staff communication about 30% of the time, juvenile to juvenile communication about 18% of the time and staff to staff communication the most infrequently. The percentages of the reported SME examples by category are displayed in Figure 2 below.

Hearing-Critical Sounds During Routine Day	
Phones, intercoms, radios, alarms	29.41%
Sounds prompting investigation (scraping objects, thumps)	26.47%
Door locks engaging (ensuring security doors locking)	20.59%
Other	11.76%
Juvenile movement within the facility	8.82%
Physical altercations	2.94%
Hearing-Critical Sounds During Emergencies or Incidents	
Juvenile pounding, throwing, hitting, scraping objects	35.29%
Juvenile to juvenile physical altercations	29.41%
Intercoms, radios, alarms	29.41%
Other	5.88%
Speech Communications During Routine Day	
Radio/intercom/phone communication	29.41%
Juvenile/juvenile communication	26.47%
Staff /detainee communication	23.53%
Staff/staff communication	20.59%
Speech Communications During Emergencies or Incidents	
Radio/intercom/phone communication	47.06%
Staff/staff communication	29.41%
Juvenile/juvenile communication	17.65%
Staff/juvenile communication	5.88%

Figure 2: Percentage of SME Examples by Category

Estimated Background Noise Levels

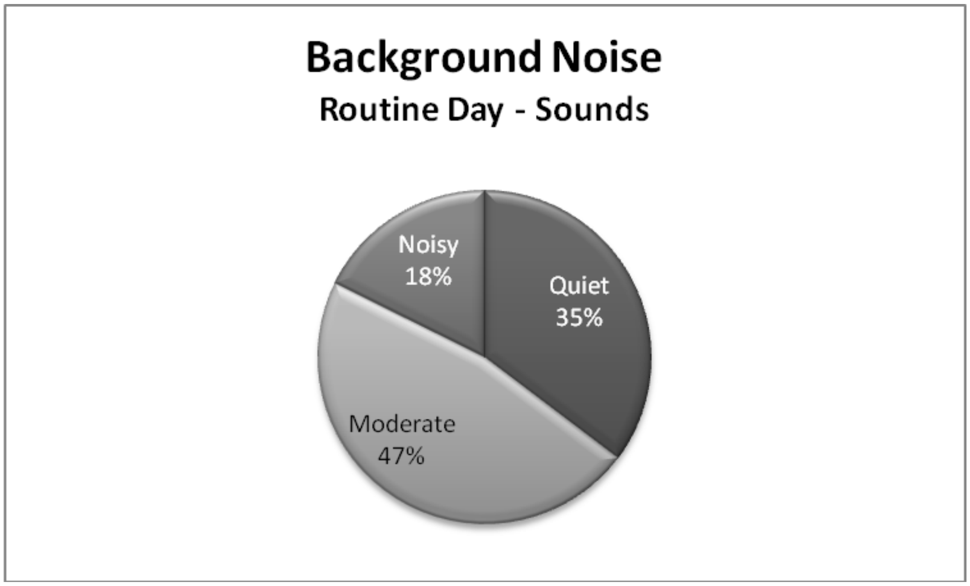


Figure 3: Background Noise Levels for Sounds During Routine Day

When listening for sounds during a routine day, the SMEs reported the background noise level as moderate 47% of the time, quiet 35% of the time, and noisy 18% of the time. (See Figure 3)

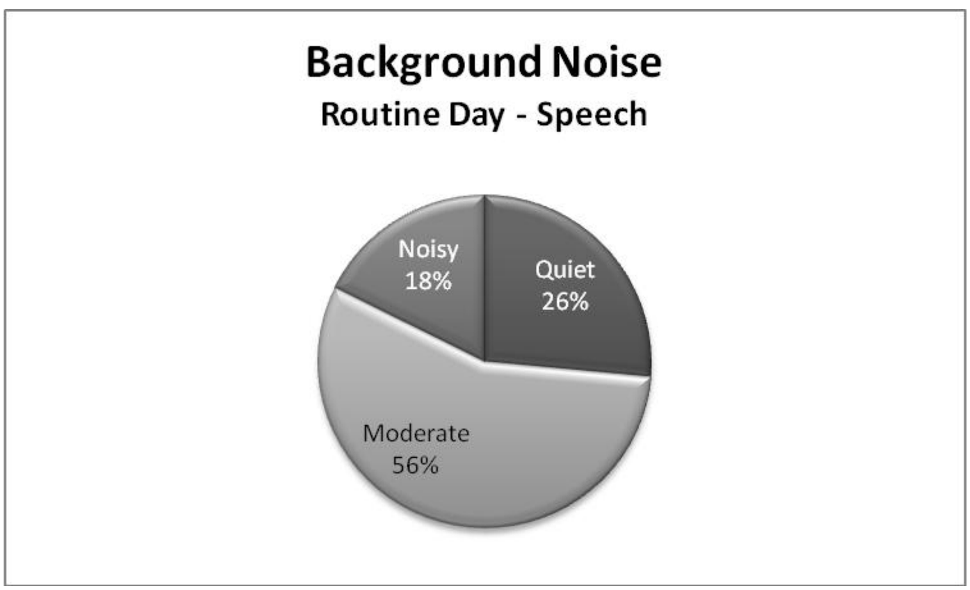


Figure 4: Background Noise Levels for Speech Communication During Routine Day

When listening for speech communication during a routine day, the SMEs reported the background noise level as moderate 56% of the time, quiet 26% of the time, and noisy 18% of the time. (See Figure 4)

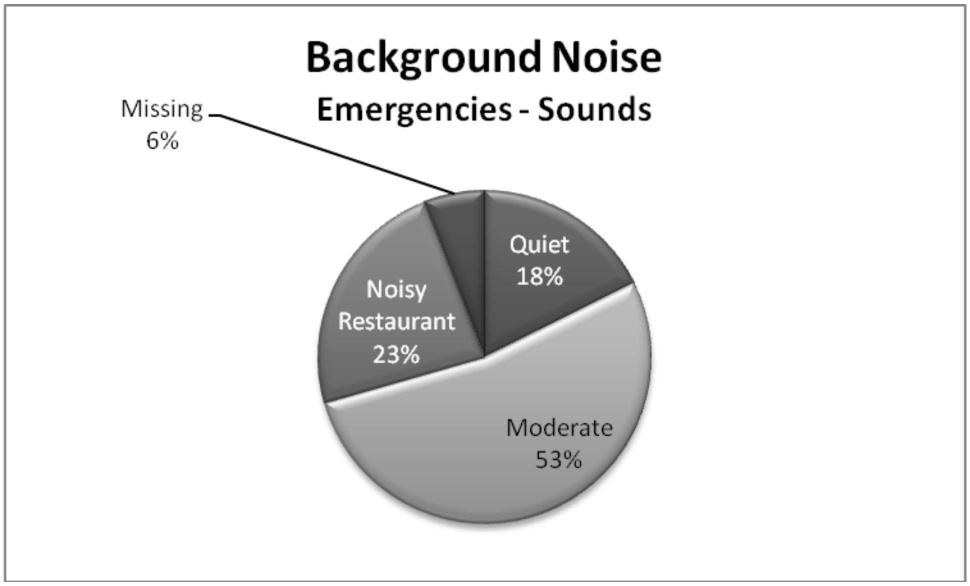


Figure 5: Background Noise Levels for Sounds During Emergencies

When listening for sounds during emergencies or incidents, the SMEs reported the background noise level as moderate 53% of the time, noisy 23% of the time, and quiet 18% of the time. (See Figure 5)

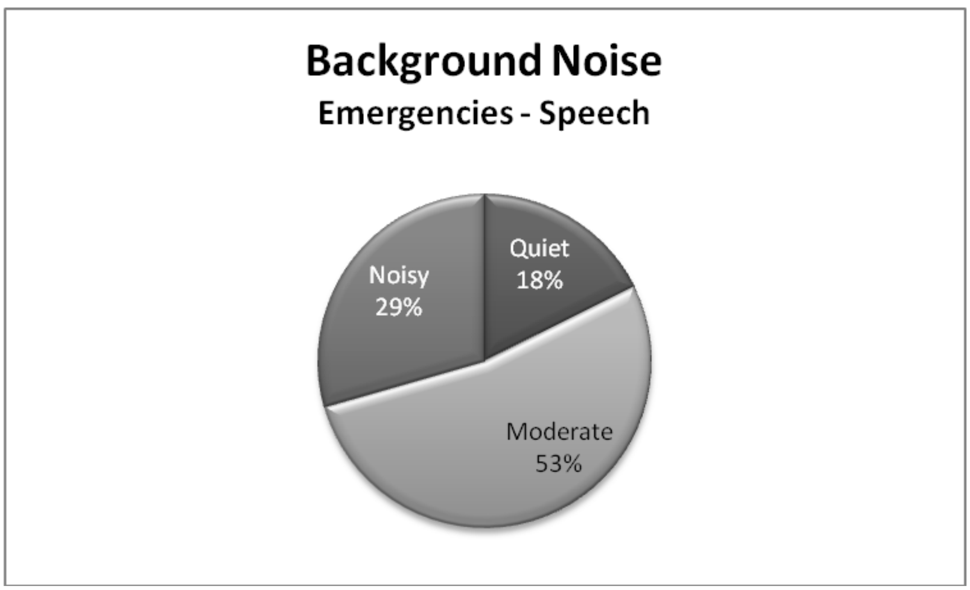


Figure 6: Background Noise Levels for Speech During Emergencies

When listening for speech communication during emergencies or incidents, the SMEs reported the background noise level as moderate 53% of the time, noisy 29% of the time, and quiet 18% of the time. (See Figure 6)

Sound Source Visibility

The SMEs reported that when listening for sounds during a routine day, the sound source was not visible about 60% of the time. During emergencies, the sound source was not visible 76% of the time.

The SMEs reported that when listening for speech during a routine day, the speech source was not visible 41% of the time. During emergencies, the speech source was not visible 53% of the time.

Opportunity to Repeat Speech Communication

During both a routine day and during emergencies, officers were able to request that speech communications be repeated about 80% of the time if the initial communication was not understood. While the majority of time communications can be repeated, SMEs noted that the sooner the speech was understood during an emergency, the quicker help is rendered.

Voice Levels

The SMEs reported that during a routine day, the most common voice level of speech communication they heard was a normal voice level (62%). There were five reported examples of speech communication at the whispered/softy spoken level. Juvenile Corrections Officers explained that it is sometimes necessary to "eavesdrop" on softly spoken conversations between juveniles to supervise the group effectively. Officers sometimes hear juveniles' plans to disrupt the group, pick a fight, or pass contraband. For the remaining examples, raised voice levels were heard about 18% of the time; and shouted voice levels were heard about 6% of the time.

During emergencies, the SMEs reported that a raised voice level was heard 41% of the time, a shouted voice level was heard about 35% of the time, a normal voice level was heard about 12% of the time, and whispered/softly spoken speech was heard about 6% of the time.

SMEs Rated Importance of Speech Communication

All of the SMEs interviewed rated the importance of speech communication as very important. Officers emphasized this ability by using such phrases as "couldn't do job without it"; "crucial" and "essential."

Discussion

The interviews expanded the research team's understanding of the importance of an officer's ability to hear. SMEs provided evidence that the ability to understand speech communication is critical to the successful performance of the job. If Juvenile Corrections Officers do not have adequate hearing ability, they may be unable to maintain security and prevent injury or even the death of a juvenile detainee.

STEP 4: PRIMARY FUNCTIONAL HEARING ABILITY

The fourth step in the research strategy was to determine the primary functional hearing ability to be examined throughout the remainder of the research.

Background and Rationale

The analysis of the incident reports and the results of the interviews with Juvenile Corrections Officers clearly pointed to the criticality of speech communication as a functional hearing ability. These findings have important implications for the hearing guideline and for the screening measures used in the selection of applicants for the Juvenile Corrections Officer job.

Methodology

To determine if speech communication was the primary functional hearing ability for the Juvenile Corrections Officer job, research staff addressed several issues. The first was to determine whether there is adequate evidence of its importance. The second was to evaluate the significance of negative consequences of failed or ineffective speech communication. The third was to justify the consideration of speech communication at the exclusion of detection, recognition, and localization of non-speech sounds. The fourth was to assess whether there is sufficient scientific knowledge showing how background noise affects the ability to communicate with speech for the purpose of hearing screening. Finally, the fifth step was to identify well-established measures of speech communication that can be used for hearing screening. Each of these issues is addressed in turn below.

Results

Importance of Speech Communication

Several aspects of the information gained from the Juvenile Corrections Officers interviews and from analyses of the incident reports sharpened the focus of the research on speech communication. There was repeated evidence that speech communication between Juvenile Corrections Officers and between officers and juveniles were frequent and hearing-critical job functions. Additionally, Juvenile Corrections Officers routinely monitor the speech communication between juveniles. These activities are vital to safety of the juveniles and the security of the facility. There was also repeated evidence that speech communication occurred in moderate to loud background noise levels approximately 75% of the time during routine days and approximately 80% of the time during emergencies. Further, there was evidence that Juvenile Corrections Officers often found it necessary to use loud or shouted vocal effort as well as repetition, and to achieve effective speech communication. Further, effective speech communication was found to be of critical importance in maintaining the health and safety of juveniles and Juvenile Corrections Officers, for example:

- Notifying the necessary personnel of a medical emergency
- Instructing juveniles to cease certain actions
- Providing crisis counseling to distressed juveniles

Consequences of Failed Speech Communication

The consequences of failed speech communication in a juvenile detention facility are considerable. These include injury to, even death of, detained juveniles, inappropriate response to medical emergency, suicide, and escape. These consequences of failed speech communication can seriously jeopardize the health and safety of individuals in the detention environment as well as the public.

Consideration of Non-Speech Sounds

The functional hearing abilities related to non-speech sounds are customarily defined as sound detection, sound recognition, and sound localization. However, for effective speech communication to occur, the speech sounds must also be detected, recognized, and, to some extent, localized. (When speech recognition is measured in noise with the speech and noise originating from different locations, the speech and noise are distinguished auditorily by their different locations.) Thus, if appropriate measures of speech communication are used for screening, evidence of adequate speech communication ability implies adequate non-speech functional hearing abilities.

Scientific Knowledge about Speech Communication in Noise

There is a substantial body of research literature that has examined the effects of noise on speech communication. (See Tufts et al., 2009, for a review.) Much of this literature has focused on how hearing impairment alters the ability to understand speech in noise. A standardized metric, the *Speech Intelligibility Index* (SII), has been used for many years to quantify the ability to understand speech in noise. Application of this metric to the prediction of speech understanding in everyday noise environments, such as those encountered by Juvenile Corrections Officers, has also been validated (Rhebergen & Versfeld, 2005; Rhebergen et al., 2006, 2008). This scientific knowledge, together with the SII standard, can be used for the purpose of hearing screening when speech communication in noisy environments is the primary functional hearing ability of interest.

Available Measures of Speech Communication in Noise

In recent years, a number of measures of speech communication in noise have been developed and published (e.g., Nilsson et al., 1994; Killion & Niquette, 2000; Bentler et al., 2000; Bilger et al., 1984; Cox et al., 1988; Kalikow et al., 1977). There is also a substantial body of both theoretical and applied research on the use of these measures and on the practical significance of the scores obtained with these measures. Recent studies have established a scientific link between this research and the research on speech communication in noise described above.

Discussion

Each of the issues presented above is relevant to the focus on speech communication as the primary functional hearing ability required for the Juvenile Corrections Officer job. This emphasis on speech communication concentrated the research efforts on objective measures of the noise environment where speech communication takes place within the juvenile detention facilities.

Step 5: Selection of Juvenile Facilities for On-Site Observations and Measurements

The fifth step in the research strategy was to select a representative sample of juvenile facilities for on-site observations and noise measurements.

Background and Rationale

The research strategy called for on-site visits to a number of juvenile facilities for observation of hearing-critical job functions where speech communication was the primary functional hearing ability. The research team designed a sampling plan that identified representative facilities throughout the state.

Methodology

A number of different factors were considered in forming a representative sample of juvenile facilities from throughout the State of California. These included the size of the facility, the type of facility, and its geographical location. The size of the facility was determined by its rated capacity; although not all facilities are occupied to capacity at all times. Types of juvenile facilities fell into two broadly defined categories, juvenile halls and juvenile camps. Geographical location was most easily defined by identifying whether facilities are found in the northern, central, or southern portions of the state.

Results

The research team selected 28 juvenile facilities for observation and measurement. These facilities were distributed throughout all regions of the state, with a wide range of rated capacities. Table 8 lists these facilities. Analyses of the logs and recordings from each facility revealed that in most cases the predominant source of background noise that could interfere with speech communication was the voices of juveniles and the other sounds they made. Thus, the number of juveniles present during observations and recordings, as estimated from the rated capacity of the facilities, becomes an important consideration. Because of this consideration, Table 8 and the subsequent analyses are based in part on groupings of the measurements by rated capacity of the facilities where they were made. These facilities include 3 camps and 25 juvenile halls. Recordings were made at these facilities between March 2011 and December 2011.

Discussion

The facility sampling plan produced approximately equal numbers of facilities within each range of rated capacities. Both camps and juvenile halls were included.

Table 8: Selected Facilities for Background Noise Level Measurements

Juvenile facilities visited for observations and measurements. Facilities are grouped by rated capacity (RC).

Nr	Name of Facility	RC
Rated capacity ≤ 60		
1	Butte County Juvenile Hall	60
2	Del Norte County Juvenile Hall	20
3	El Dorado County Juvenile Hall	40
4	Humboldt County Juvenile Hall	26
5	Lake County Juvenile Hall	40
6	Merced Juvenile Justice Corrections Complex	60
7	Placer County Juvenile Detention	58
8	San Diego Girls' Rehabilitation Facility	50
Rated capacity >60 - 240		
1	Alameda County Camp Sweeney	105
2	Fresno County Juvenile Justice Campus	210
3	Fresno County Juvenile Justice Campus Commitment Facility	240
4	Kern County Camp Erwin Owen	125
5	Kern County James G. Bowles Juvenile Hall	170
6	Los Angeles County Camp Glen Rockey	125
7	Orange County Youth Leadership Academy	120
8	Orange County Youth Guidance Center	125
9	San Bernardino County Central Valley Detention and Assessment Center	168
10	Solano County Juvenile Hall	118
11	Yolo County Juvenile Hall	90
Rated capacity >240		
1	Alameda County Juvenile Justice facility	358
2	Los Angeles County Central Juvenile Hall	623
3	Los Angeles County Barry Nidorf Juvenile Hall	597
4	Los Angeles County Los Padrinos Juvenile Hall	604
5	Orange County Juvenile Hall	434
6	Sacramento County Youth Detention Facility	270
7	San Diego County East Mesa Juvenile Hall	290
8	San Diego County Kearney Mesa Juvenile Hall	359
9	Santa Clara County Juvenile Hall	390

STEP 6: SELECTION OF LOCATIONS AND TIMES FOR ON-SITE OBSERVATIONS AND MEASUREMENTS

The sixth step in the research strategy was to select locations and times within each facility where hearing-critical job functions take place.

Background and Rationale

For each of the facilities sampled in the previous step research staff identified the locations and times where Juvenile Corrections Officers perform hearing-critical job functions involving speech communication. Staff used this information to plan on-site visits to observe and document the performance of these functions and to record the background noise.

Methodology

Locations and times at each facility were identified from the information obtained from interviews with SMEs and from the locations where reportable incidents most commonly occurred. Staff used this information to form a prioritized list of the most important times and locations to be visited at each facility.

Top priority was assigned to locations where Juvenile Corrections Officers spend a substantial amount of time and where they perform a number of hearing-critical job functions involving speech communication. The information in the list was not facility-specific, as it represented the information obtained and compiled from Juvenile Corrections Officers working in facilities across the entire state. Thus, as a second step, the research team conducted interviews with Juvenile Corrections Officers who worked at each facility at the beginning of each on-site visit. Research staff reviewed the prioritized list with the Juvenile Corrections Officers at each facility and asked how the list could best be adapted to the specific locations and schedules in place at their facility. After any needed adjustments were made to the list, research staff planned a detailed schedule for visiting each location.

Results

Table 9 shows the prioritized list of locations and times for on-site visits identified from the interviews with SMEs and analysis of incident reports. Officers most frequently stated that mornings are generally quiet as juveniles are in classrooms. Late afternoons and evenings, especially on the weekends tend to be the noisiest. However, officers also pointed out that there is no set pattern. Noise levels are affected by the composition of detainee population as well. Officers reported that one unruly detainee can make considerable noise by yelling and banging in his/her room.

Table 9: Prioritized List of Locations Targeted for Observation, Sound Measurements, and Recordings

Location
Housing
Outdoor recreation
Classroom
Receiving
Dining
Indoor recreation
Movement areas
Kitchen
Visiting
Medical
Control

Discussion

The prioritized list of locations for on-site recordings of background noise environments provided an efficient way to ensure that the research team observed the most important hearing-critical job functions involving speech communication. The pre-observation interviews identified specific spots at each location that were noisiest or where the most important speech communication activities occurred. Time schedules were also set to make the most efficient use of time available at the facility.

The on-site visits to each location at each facility allowed research staff to obtain observations and recordings that objectively documented the functional hearing requirements for Juvenile Corrections Officers. The following steps describe how the recordings were made, analyzed, and interpreted for this purpose.

Step 7: Background Noise Recordings And Measurements

The seventh step in the research strategy was to record and measure background noise environments where hearing-critical job functions occur.

Background and Rationale

The intended use of the background noise recordings was to provide quantitative information about the noise environments where Juvenile Corrections Officers must achieve effective speech communication to perform hearing-critical job functions throughout the routine day and during responses to incidents. By making calibrated recordings of these noise environments, it was possible to use a standardized metric, the Speech Intelligibility Index (American National Standards Institute, 2007), to predict the likelihood that otologically normal Juvenile Corrections Officers can achieve this level of performance. Published methods for calculating the SII and for making these predictions are available for this purpose. These methods have recently been extended to apply to everyday noise environments, such as those encountered by Juvenile Corrections Officers in a routine day.

Use of the Extended SII methods requires that the moment-to-moment variations in noise level and frequency be known. With calibrated recordings of the noise environments at appropriate times and locations, well-defined methods of analysis (American National Standards Institute, 2007) can be used to process the recordings, providing the necessary details about the level and frequency of the noise. These details, in turn, can be used to determine the likelihood of effective speech communication in each noise environment. The same methods can also be used subsequently to determine how hearing impairment affects performance. The detailed methodology for making these recordings is summarized in Appendix D. A summary of the key aspects of the methodology is given below.

Methodology

All recordings were made using a hand-held digital audio recorder, the Edirol R-09HR manufactured by Roland. Recordings were stored on a digital memory card and later transferred to a personal computer for data processing and analysis. Procedures for calibration of the recordings are given in Appendix E.

Results

The research team made a total of 124 recordings at the specified locations from the 28 facilities. A detailed summary of each recording is given in Appendix F.

Table 10 presents a brief summary of the recordings. The recordings are organized according to location within the facilities. For each location, e.g., "classroom," the number of facilities and the total number of recordings is given. Note that in many cases there were more recordings than facilities, indicating that multiple recordings were made at the same location within some facilities.

Table 10: Summary of Recordings by Facility and Location

Total number (Nr) of noise recordings for each visited facility and number of recordings at each location within the facility. Facilities are grouped by rated capacity.

Location	Nr	Recv	Chow	Cont	Gym	Hous	Kitch	Med	Move	Rec	Visit	Schl
Butte JH	6					2	2		1	1		
Del Norte JH	4			2	1	1						
El Dorado JH	6		1			2			1	2		
Humboldt JH	6		1		3	2						
Lake JH	5			1		2			1			1
Merced JH	2					2						
Placer JD	4	1		1								2
San Diego GRF	7					6				1		
Subtotals	40	1	2	4	4	17	2	0	3	4	0	3
Alameda Camp WS	3			1						1		1
Fresno CF	6		2			3				1		
Fresno JH	3					3						
Orange County YLA	2		2									
Orange County YGC	3		2				1					
Kern Camp O	1					1						
Kern JH	4		2			2						
LA Camp GR	7		4			1	1					1
San Bernardino JDC	8					3		1	1	1	2	
Solano JH	1					1						
Yolo JH	2					2						
Subtotals	40	0	12	1	0	16	2	1	1	3	2	2
Alameda JH	6				2	3						1
LA Central JH	5	1				1		1				2
LA Barry Nidorf JH	5		1		1					3		
LA Los Padrinos JH	3	2							1			
Orange JH	3									3		
Sacramento JH	5				1	2				2		
San Diego EMJD	1			1								
San Diego KMJDF	9		1	1		5				2		
Santa Clara JH	7		1		2	3			1			
Subtotals	44	3	3	2	6	14	0	1	2	10	0	3
OVERALL TOTALS	124	4	17	7	10	47	4	2	6	17	2	8

Note: Recv = Receiving, Chow = Dining, Cont = Control, Gym = Indoor Rec, Hous = Housing, Kitch = Kitchen, Med = Medical, Move = Movement, Rec = Outdoor Rec, Visit = Visitation, Schl = School

Discussion

The noise recordings provide a representative sample of the noise environments where Juvenile Corrections Officers perform hearing-critical job functions throughout the routine day and during responses to incidents. The sample includes data from a representative set of facilities throughout the state.

The sample includes only recordings made at locations and times where important hearing-critical job functions involving speech communication occur. Thus, subsequent analyses based on the SII standard and the published methods that extend these analyses to everyday noise environments allow an accurate characterization of the likelihood that otologically normal Juvenile Corrections Officers can achieve effective speech communication when performing hearing-critical job functions at these locations.

STEP 8: ANALYSIS OF NOISE RECORDINGS

The eighth step in the research strategy was to perform standardized analyses of the noise recordings.

Background and Rationale

The Speech Intelligibility Index (SII) is a standardized metric for predicting speech intelligibility, or speech understanding, in stationary non-fluctuating noise (American National Standards Institute, 2007). The SII has recently been extended to predict speech intelligibility in fluctuating noise as well, such as found in everyday noise environments (Rhebergen & Versfeld, 2005; Rhebergen et al., 2006, 2008). The Extended SII, or ESII, can be used to predict speech intelligibility and the likelihood of effective speech communication for otologically normal Juvenile Corrections Officers in each of the noise environments where they perform hearing-critical job functions throughout a routine day and during responses to incidents.

The SII and ESII are based on the principal that the level of the information in speech in relation to the level of the noise determines intelligibility and the likelihood of effective speech communication. The importance of information in speech for intelligibility and effective communication is not the same at all frequencies. For example, speech information below 2000 Hz is more important than speech information above 2000 Hz. To calculate the SII and ESII it is necessary to filter the noise into narrow frequency regions and to determine the level of the noise in each region. The level of speech in each frequency region is stated in the standard (American National Standards Institute, 2007). The level of the speech in relation to the noise in each frequency region, together with the importance of the speech information in each region, allow the SII and ESII to be calculated.

The speech levels used to calculate the SII and ESII can vary depending on the vocal effort used to produce the speech. The standard allows a “normal,” “raised,” “loud,” or “shouted” level of vocal effort to be specified. All four levels of vocal effort are appropriate for use in the analyses because SMEs reported and research staff observed on-site regular use of these levels of vocal effort by Juvenile Corrections Officers.

The standard also allows communication distance to be specified. Again, the SME reports as well as the observations during on-site recordings indicated that relatively short communication distances were commonly used because of high background noise levels.

In fluctuating background noise there are times when the noise level drops, making speech communication easier and more effective. There also are times when the noise level increases, making speech communication more difficult and less effective. Thus, it is appropriate to consider the likelihood of effective speech communication in fluctuating background noise. The ESII provides an effective means of quantitatively characterizing this likelihood for otologically normal individuals. The ESII for a fluctuating noise environment is determined by first calculating the SII over and over on brief "snapshots" of the noise, approximately 100 per second, and then averaging these values over the entire duration of the noise (Rhebergen & Versfeld, 2005; Rhebergen et al., 2006, 2008). This method can be readily adapted to determine the ESII for a segment of the noise, rather than the entire duration of the noise. The standard states that "good" speech communication can occur when the SII exceeds 0.45. This also applies to the ESII; however, when binaural hearing and the opportunity to repeat communications are considered, this value decreases to 0.30. Appendix G provides the detailed rationale for using 0.30 as the criterion value.

Most brief two-way communications between individuals take place over a few seconds, e.g., 4 seconds. Thus, by calculating the ESII for a 4 second segment of the noise it is possible to determine whether effective speech communication can occur during that segment. ESII values over 0.30 indicate that it can, and values under 0.30 indicate that it cannot. Finally, if an entire on-site noise recording is divided into 4 second segments and the ESII for each segment is calculated, the percent of segments with ESII values over 0.30 corresponds to the percent of time effective speech communication can occur in the fluctuating noise environment. This percentage is defined as the likelihood of effective speech communication in that noise environment for an otologically normal individual.

Research staff used these analyses to determine the likelihood of effective speech communication for Juvenile Corrections Officers with normal hearing at the times and locations where Juvenile Corrections Officers perform the most important hearing-critical job functions involving speech communication. Research staff also repeated these analyses to determine the type and degree of hearing impairment that reduces the likelihood of effective speech communication to a level where safe and effective job performance could become an issue. This approach provides an explicit and objective connection between the measures of hearing impairment to use for screening applicants for the job and the hearing-critical job functions that Juvenile Corrections Officers must perform during a routine day and when responding to incidents.

Methodology

The recordings were processed according to the procedures specified in the standard (American National Standards Institute, 2007). The noise was filtered into 1/3 octave bands with center frequencies ranging from 160 Hz to 8000 Hz. Calibrations were applied to each noise band, and the SII was calculated every 9.2 milliseconds from noise "snapshots" and averaged over 4 second intervals to produce ESII values. These calculations were repeated for several levels of vocal effort and several communication distances. Cumulative frequency distributions of the resulting ESII values were formed. These ESII data sets were used to determine the likelihood of effective speech communication for various combinations of vocal effort and communication distance at each location and time at each facility where Juvenile Corrections Officers perform hearing-critical job functions. A detailed description of this methodology is given in Appendix H.

Results

Research staff processed each of the 124 recordings according to the procedure described above to produce an ESII data set for each recording. Of primary interest were the cumulative distributions of ESII values from each location. Analysis of these distributions quickly revealed that the ESII values for communication distances of 5 and 10 meters were uniformly low, often 0.00. Consequently, these two communication distances were not included in the subsequent analyses.

Discussion

The 124 ESII data sets represent measurements and analyses from 11 different locations at 28 different juvenile detention facilities. The size of each data set, as well as the number of data sets from each location and each facility, varied in an unsystematic manner, complicating interpretation of the analyses. These considerations made it necessary to pool and weight the ESII data sets to control these unsystematic variations. The next step in the research strategy addressed these considerations.

Step 9: Likelihood Estimates of Effective Speech Communication

The ninth step in the research strategy was to estimate the likelihood of effective speech communication for noise environments throughout a routine day in juvenile facilities.

Background and Rationale

One of the primary observations by the research staff about the noise levels observed during the recordings was that these levels appeared to be directly related to the number of individuals present at the location where the recordings were being made. In other words, the primary noise source for many locations was the sound produced by individuals. The more individuals present, the greater the noise level. Since it was not possible to accurately determine, especially after the fact, the number of individuals present during recordings, the rated capacity of the facility where the recordings were made was used instead as an estimate of the number of individuals present.

In addition, there were varying numbers of recordings at the same location from different facilities. For example, one facility might have only 2 recordings from housing while another facility might have 5 recordings. Thus, it was necessary to weight the ESII data from each facility equally in determining the composite ESII data for each location.

Finally, the distribution of rated capacity for the sample of 28 facilities did not match the distribution of rated capacity for the 113 juvenile detention facilities throughout the state. These considerations made it necessary to utilize a stratified sampling plan that controlled the weighting of ESII data from facilities with different numbers of recordings and different rated capacities. The methods used to achieve appropriate weighting are described below.

Once the stratified samples of ESII data for each of the 11 locations had been formed and pooled, these data from each location were again pooled to provide a single, overall estimate of the likelihood of effective speech communication throughout the routine day of a Juvenile Corrections Officer. The data from each location were weighted according the proportion of incidents reported per location.

Methodology

The following process was repeated for each of the 11 locations given in Table 8. The first step in forming the stratified sample of ESII data sets was to equally weight the data from each facility. For example, there were 47 ESII data sets produced from recordings in housing locations at 20 different facilities. The data sets from facilities where more than one recording was made were averaged to produce a single ESII data set for each facility. In the case of housing, this produced 20 ESII data sets, one per facility.

The second step was to group the data sets according to the rated capacity of the facilities from which they originated. The 28 facilities in the sample were divided into three groups of approximately equal size. The facility names, number of recordings per facility, and rated capacity of each facility are reported in Appendix F.

Table 11 shows that the first group was comprised of facilities with rated capacities of 60 or less. Of all local juvenile detention facilities, 42.6% fall within this range. The second group from the sample consisted of facilities with rated capacities of 60 to 240. Of all facilities, 47.8% are in this range. The third group from the sample included facilities with rated capacities greater than 240, which represents 9.6% of all local juvenile detention facilities in the state.

Table 11: Distribution of Rated Capacity in Sampled Juvenile Facilities and in all Local Juvenile Detention Facilities

Rated capacity	Sample facilities	Percent of all facilities
≤ 60	8	42.6%
60 - 240	11	47.8%
> 240	9	9.6%

The third step was to average the ESII data sets from the facilities in each capacity group to produce a single data set for each capacity group. For example, the ESII data sets were averaged from the 8 facilities in the first group with rated capacity less than 60.

The fourth step was to weight the three ESII data sets representing each capacity group by the percent of total facilities falling within that group. Again, for example, the values in the data set representing the first group were multiplied by 0.426. The weighted values in the three ESII data sets were then summed to produce a single data set for the location, based on a representative sample of facilities throughout the state. This process was repeated for each of the 11 locations.

The fifth step was to combine the ESII data sets for each location in a manner that represents the hearing requirements for the routine day of a Juvenile Corrections Officer. The data sets from each location were weighted according to the proportion of reported incidents involving hearing that occurred at these locations. These proportions were calculated from the 402 incident reports analyzed for this study. Absolute proportions were used as weights for locations with 2% or more of all reported incidents. The remaining unallocated proportion of incidents was divided equally among the locations with less than 2% of incidents.

The final step involved accessing the ESII data sets for each location to determine the likelihood of effective speech communication at each location, given a specified ESII value. For example, otologically normal individuals require an ESII of 0.30 or greater for effective communication. The proportion of 4 second segments that exceed 0.30 in the ESII data sets for each location was determined, and these proportions were weighted by the proportions for each location defined in the previous analysis step. The sum of the products of these two proportions over the 11 locations gives the overall likelihood of effective speech communication throughout a Juvenile Corrections Officer's routine day.

Results

Table 12 summarizes the results of the pooling and weighting process. The weights in column 4 are based on the proportion of reports from each location describing incidents that involved hearing-critical job functions. Indoor Recreation, for example, was weighted 0.04, and kitchen areas received a weight of 0.01. Housing received a weight of 0.64, the largest weight allocation for any of the locations, reflecting the importance of hearing-critical job functions performed in and around the housing area.

The final columns in Table 12 provide the likelihood of effective speech communication at a close distance of 0.5 meters under different levels of vocal effort. The levels of vocal effort represented are normal voice, raised voice, loud voice, and shouted voice (N, R, L, and S, respectively).

To illustrate how to read the information in Table 12, consider Outdoor Recreation. The pooled ESII data for this location was from 17 different recordings made at 10 different facilities. The likelihood of effective speech communication using normal vocal effort at a distance of 0.5 meters is 0.77. This likelihood increases to 1.0 for raised, loud, and shouted levels of vocal effort. These likelihood values are weighted by 0.10 when combined with the other weighted likelihood values to produce the overall estimate of the likelihood of effective speech communication throughout an entire day. In the example shown in the table, the overall likelihood estimate is 0.79 when normal vocal effort is used. This value increases to higher likelihoods as vocal effort is increased, and reaches 1.00 with loud and shouted vocal effort.

Table 12: Results of Pooling and Weighting Process

Locations selected to comprise the routine day of a Juvenile Corrections Officer for communication at a distance of 0.5 meters. Shaded cells represent locations with fewer than 2% of the incidents and were assigned equal weights of 0.01.

Location	Facilities	Recordings	Weight	N	R	L	S
Housing	20	47	0.64	0.78	0.93	1.00	1.00
Classroom	6	8	0.09	0.96	1.00	1.00	1.00
Outdoor rec	10	17	0.10	0.77	0.99	1.00	1.00
Dining	10	17	0.04	0.82	0.98	1.00	1.00
Receiving	3	4	0.05	0.95	1.00	1.00	1.00
Indoor rec	6	10	0.03	0.33	0.88	0.99	1.00
Movement	6	6	0.02	0.96	1.00	1.00	1.00
Kitchen	3	4	0.01	0.00	0.24	0.88	1.00
Visiting	1	2	0.01	0.92	1.00	1.00	1.00
Medical	2	2	0.01	0.99	1.00	1.00	1.00
Control	6	7	0.01	0.99	1.00	1.00	1.00
Overall likelihood of effective communication				0.79	0.95	1.00	1.00

Note. For Vocal Effort: N = Normal; R = Raised; L = Loud; S = Shouted.

Discussion

The results of pooling and weighting the ESII data sets to estimate the likelihood of effective speech communication throughout a Juvenile Corrections Officer's routine day provide several objective insights into the hearing requirements for the job. The data in Table 12, which apply only to otologically normal Juvenile Corrections Officers, reveal that even these individuals do not experience a high likelihood of effective speech communication at all times. For example, speech produced with normal vocal effort is likely to result in effective communication less than 80% of the time throughout the day. This likelihood increases to 95% with raised vocal effort, and reaches 100% with loud or shouted speech. In the noisiest locations, e.g., kitchen and indoor recreation, only loud or shouted speech at short distances results in effective speech communication. In the location with the highest weight, i.e., housing, raised or loud vocal effort usually can result in effective speech communication.

Effective speech communication is challenging for all Juvenile Corrections Officers at numerous times and locations throughout the routine day. However, it may be even more challenging more often for hearing impaired individuals. The next step in the research strategy was to examine how hearing impairment, as measured by elevation of the speech reception threshold in noise, affects the likelihood of effective speech communication in the challenging noise environments where Juvenile Corrections Officers must perform hearing-critical job functions that include communication with speech.

STEP 10: IMPACT OF HEARING IMPAIRMENT ON LIKELIHOOD ESTIMATES

The tenth step in the research strategy was to determine the impact of hearing impairment on the likelihood of effective speech communication.

Background and Rationale

The ESII calculations described above apply to otologically normal individuals (American National Standards Institute, 2007). These calculations show that even with normal hearing, the likelihood of effective speech communication in some locations and on average throughout a Juvenile Corrections Officer's routine day is not always high. Thus, the question becomes how hearing impairment affects the likelihood of effective speech communication.

Hearing impairment can be quantified in terms of the need for more favorable signal/noise ratios (SNRs) to understand speech when both the speech and noise are audible, as determined by elevation of the speech reception threshold (SRT) in noise above normal. The effects of elevated SRTs are determined as follows. An individual whose SRT is elevated above normal requires a larger ESII value for effective speech communication (Houtgast & Festen, 2008). For example, an otologically normal individual requires an ESII of 0.30 or better for effective speech communication. However, an individual whose SRT is 1 dB higher (poorer) than the average requires an ESII of approximately 0.33 for effective speech communication. In other words, the ESII required for effective speech communication increases by about 0.03 for every 1 dB increase in SRT. Thus, the effects of elevated SRTs on the likelihood of effective speech communication are determined from the distribution of elevated ESII values corresponding to elevated SRTs of different magnitudes. Using this approach, research staff calculated the effects of hearing loss on the likelihood of effective speech communication throughout a Juvenile Corrections Officer's routine day for different magnitudes of SRT elevation.

Methodology

Research staff calculated ESII for each hearing loss configuration using four levels of vocal effort (normal, raised, loud, shouted) and two communication distances (0.5 meter and 1.0 meter). These calculations were used to determine the likelihood of effective speech communication for each set of parameters and each hearing loss configuration, given normal SRTs. The two greater communication distances were not included because even individuals with normal pure-tone thresholds and normal SRTs had very low likelihoods of effective speech communication at these distances.

The previous ESII calculations for otologically normal individuals were used to determine how the likelihood of effective speech communication decreases as SRTs increase, thus increasing the magnitude of the ESII required for effective communication. These analyses were performed using three different sets of ESII data. First, the ESII data from the locations throughout the routine day, as weighted by the proportion of incident reports from each location that involved hearing, were analyzed to determine the effects of increased SRTs on the likelihood of effective speech communication throughout the day over locations. Second, the ESII data from only the Housing location, where the majority of incidents (64%) involving hearing occurred, were analyzed. Third, the ESII data from Outdoor Recreation, which was one of the noisiest locations with lower ESII values, was also analyzed. Although only 10% of reported incidents involving hearing occurred at this location, the importance of effective speech communication in responding to these incidents must be considered together with the analyses for an entire routine day.

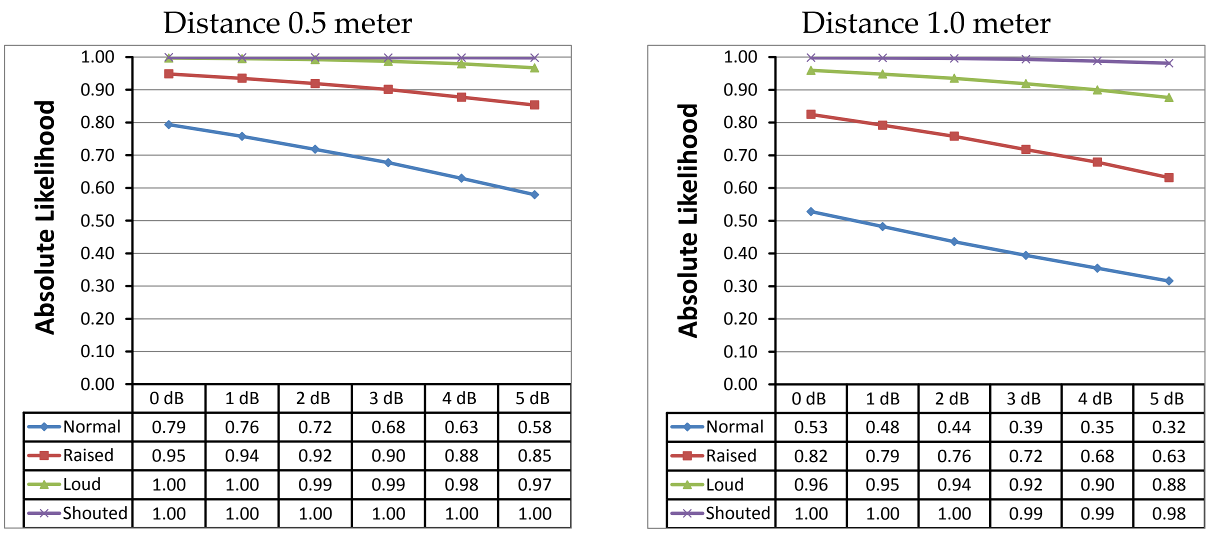
Results

The results of these analyses are reported in several sets of charts. The first set of charts displays the estimated absolute likelihood of effective speech communication at 0.5 and 1.0 meter communication distances for the entire routine day of the Juvenile Corrections Officer, for the Housing location, and for the Outdoor Recreation location. Four traces are plotted on each chart corresponding to normal, raised, loud, and shouted vocal effort. These traces are plotted as a function of SRT elevation over that of the average otologically normal individual. Likelihood estimates for threshold elevations of 1 dB, 2 dB, 3 dB, 4 dB, and 5 dB are reported.

The second set of charts is based on the first set and reports the proportional likelihood of effective speech communication under all of the same conditions as in the first set. Proportional likelihood for each condition is defined as likelihood expressed as a proportion in relation to the absolute likelihood seen for an otologically normal individual. For example, if an otologically normal individual is estimated to have 0.80 absolute likelihood of effective speech communication using normal vocal effort at a communication distance of 1.0 meter and an individual with an elevated SRT is estimated to have 0.60 absolute likelihood of effective speech communication under these same conditions, the proportional likelihood is 0.75 = 0.60/0.80. This method of calculating proportional likelihood takes into consideration that in noisy locations even otologically normal individuals may find effective speech communication difficult. Proportional likelihood quantifies deficits in speech communication associated with SRT elevation not on an absolute scale, but in relation to the expected performance of otologically normal individuals.

Effects of SRT Elevation on Estimates of Absolute Likelihood

Figure 7 displays estimates of absolute likelihood of effective speech communication at distances of 0.5 meter (left panel) and 1.0 meter (right panel) throughout a Juvenile Corrections Officer's routine day. Note that using normal vocal effort even at the shortest communication distances does not result in more than 0.80 likelihood of effective communication. This likelihood decreases systematically with SRT elevation. At the shortest communication distance, raised vocal effort has greater than 0.80 likelihood of effective communication regardless of SRT elevation. At 1.0 meter the likelihood for otologically normal is still greater than 0.80, but decreases to almost 0.60 for individuals with elevated SRTs. Loud and shouted vocal effort is highly effective at both communication distances, regardless of SRT elevation. These high levels of vocal effort, however, may not be appropriate in many situations.



Distance 0.5 meter

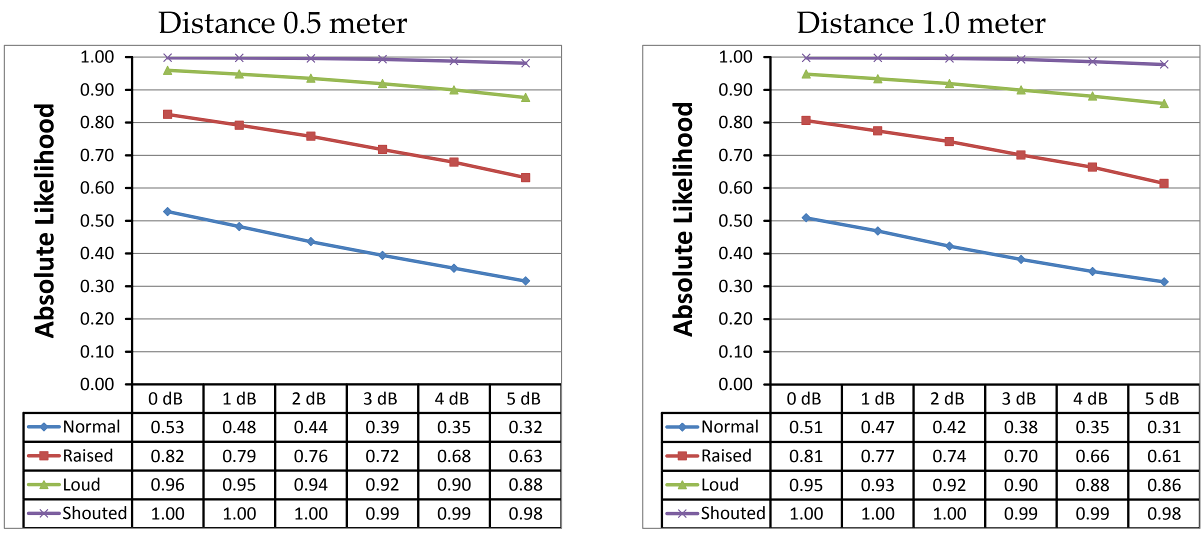
	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	0.79	0.76	0.72	0.68	0.63	0.58
Raised	0.95	0.94	0.92	0.90	0.88	0.85
Loud	1.00	1.00	0.99	0.99	0.98	0.97
Shouted	1.00	1.00	1.00	1.00	1.00	1.00

Distance 1.0 meter

	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	0.53	0.48	0.44	0.39	0.35	0.32
Raised	0.82	0.79	0.76	0.72	0.68	0.63
Loud	0.96	0.95	0.94	0.92	0.90	0.88
Shouted	1.00	1.00	1.00	0.99	0.99	0.98

Figure 7: Estimates of Absolute Likelihood of Effective Speech Communication Throughout a Juvenile Corrections Officer's Routine Day

The left panel displays results for communication distances of 0.5 meter, and the right panel displays estimates for communication distances of 1.0 meter. The vertical axes display the likelihood of effective speech communication. The horizontal axes display the SRT in dB expressed in relation to the average threshold for otologically normal individuals. The four traces in each chart display the absolute likelihood of effective speech communication using normal, raised, loud, and shouted vocal effort as a function of SRT elevation.



Distance 0.5 meter

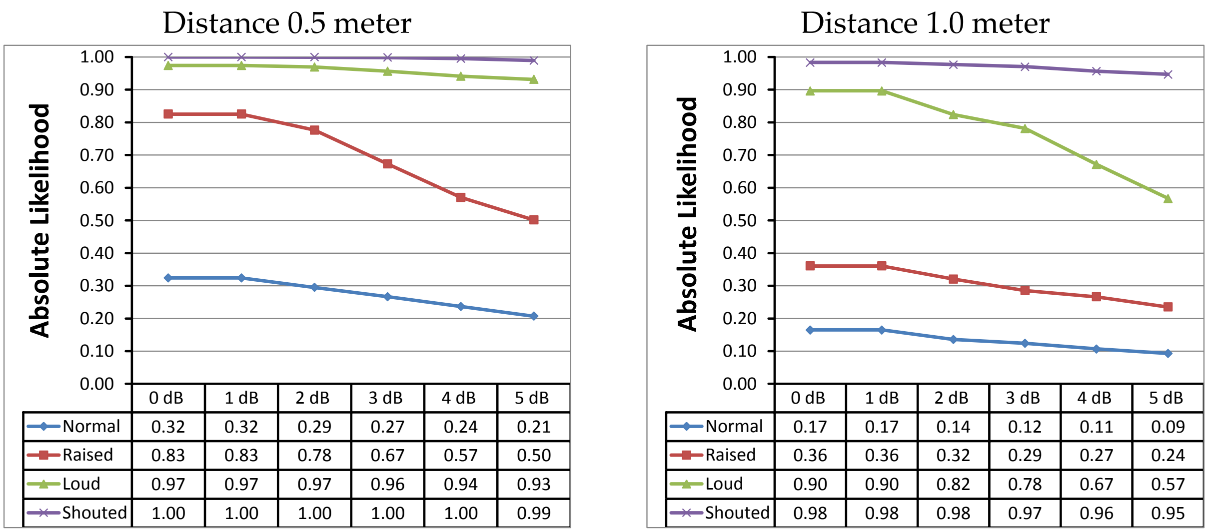
	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	0.53	0.48	0.44	0.39	0.35	0.32
Raised	0.82	0.79	0.76	0.72	0.68	0.63
Loud	0.96	0.95	0.94	0.92	0.90	0.88
Shouted	1.00	1.00	1.00	0.99	0.99	0.98

Distance 1.0 meter

	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	0.51	0.47	0.42	0.38	0.35	0.31
Raised	0.81	0.77	0.74	0.70	0.66	0.61
Loud	0.95	0.93	0.92	0.90	0.88	0.86
Shouted	1.00	1.00	1.00	0.99	0.99	0.98

Figure 8: Estimates of Absolute Likelihood of Effective Speech Communication in Housing Locations
See Figure 7 caption for details.

Figure 8 displays estimates of absolute likelihood of effective speech communication for only Housing locations in the same manner as in Figure 7. Note that 64% of incidents involving hearing took place in Housing locations, causing the ESII data set from Housing to receive a weight of 0.64. None of the weights for the remaining 10 conditions exceeded 0.10. Thus, the noise environment in a routine day is dominated by the noise environments found in Housing locations, which causes the pattern of results in Figures 8 and 9 to appear almost identical.



Distance 0.5 meter

	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	0.32	0.32	0.29	0.27	0.24	0.21
Raised	0.83	0.83	0.78	0.67	0.57	0.50
Loud	0.97	0.97	0.97	0.96	0.94	0.93
Shouted	1.00	1.00	1.00	1.00	1.00	0.99

Distance 1.0 meter

	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	0.17	0.17	0.14	0.12	0.11	0.09
Raised	0.36	0.36	0.32	0.29	0.27	0.24
Loud	0.90	0.90	0.82	0.78	0.67	0.57
Shouted	0.98	0.98	0.98	0.97	0.96	0.95

Figure 9: Estimates of Absolute Likelihood of Effective Speech Communication in Outdoor Recreation Locations
See Figure 7 caption for details.

Figure 9 displays the estimates of absolute likelihood of effective speech communication in Outdoor Recreation locations. The detailed description of the figure is the same as for the previous two figures. Only 10% of incidents involving hearing occurred at this location, giving it a weight of 0.08. Two other locations, Indoor Recreation and Kitchen, were noisier, but fewer than 4% of incidents involving hearing occurred at these locations.

The absolute likelihood of effective speech communication at 0.5 to 1.0 meter communication distances for otologically normal individuals using normal vocal effort was less than 0.40. Raised vocal effort improved the likelihood to approximately 0.40-0.90, while loud and shouted vocal effort was entirely effective. As SRT elevation increased to 5 dB over that of otologically normal individuals, likelihoods decreased systematically to as much as 0.20 at 0.5 meter and 0.10 at 1 meter. Thus, the effects of SRT elevation on the likelihood of effective speech communication are evident in this location where even otologically normal individuals require raised or loud vocal effort to communicate effectively even at short distances.

Effects of SRT Elevation on Estimates of Proportional Likelihood

Figure 10 displays estimates of proportional likelihood of effective speech communication at distances of 0.5 meter (left panel) and 1.0 meter (right panel) throughout a Juvenile Corrections Officer's routine day. These charts differ from the comparisons of absolute likelihoods shown in Figure 7 in that all likelihood values are expressed as proportions of the absolute likelihood for otologically normal individuals using the same vocal effort. Proportional likelihood values for normal vocal effort at 0.5 meter communication distances decrease to about 0.75 with increasing SRT elevation. However, with raised vocal effort they only drop to about 0.90. Note, though that the absolute likelihood of effective speech communication using normal vocal effort at 0.5 meter is only about 0.80.

A similar pattern is seen at 1.0 meter communication distances. The proportional likelihood of effective speech communication decreases to about 0.65 for normal vocal effort as SRTs increase. Decreases to about 0.75 are seen for raised vocal effort, 0.90 for loud vocal effort, and 0.99 for shouted vocal effort. The decreasing patterns of proportional likelihoods are more similar for the two communication distances than are the patterns for absolute likelihoods seen in Figure 7.

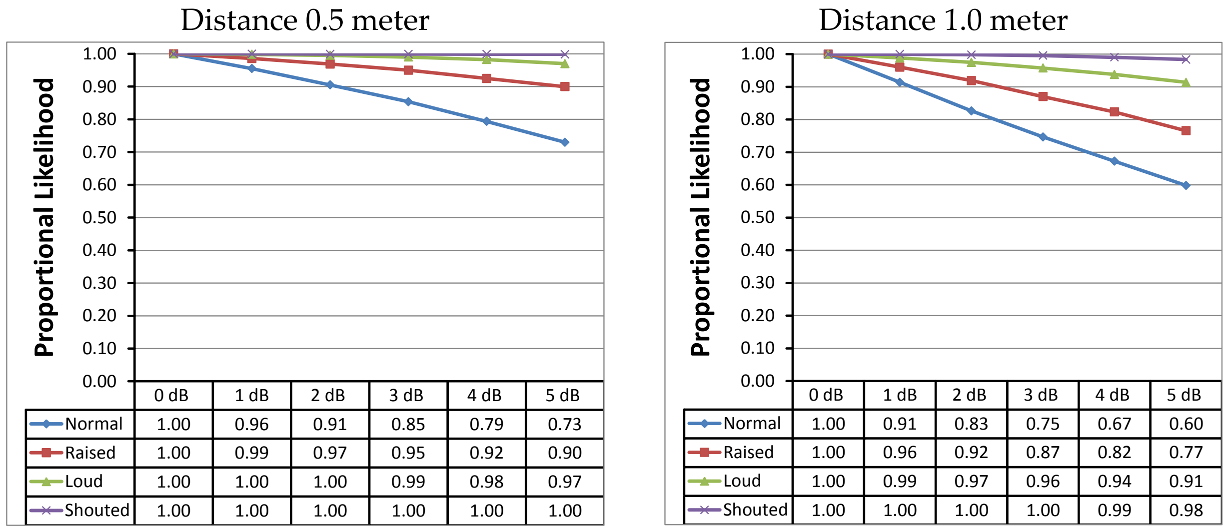
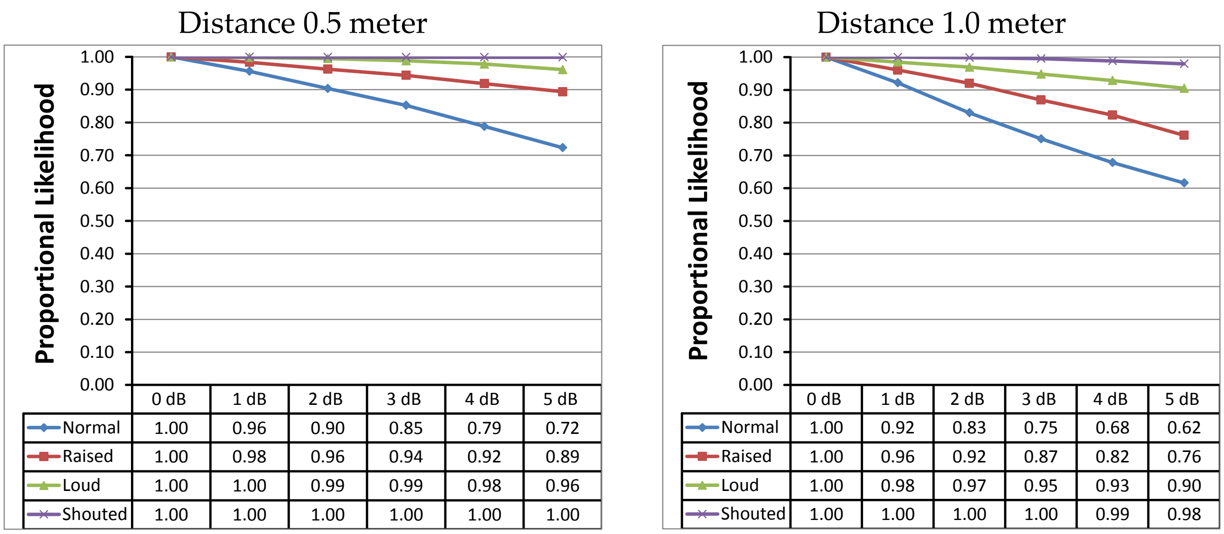


Figure 10: Estimates of Proportional Likelihood of Effective Speech Communication Throughout a Juvenile Corrections Officer's Routine Day

The left panel displays results for communication distances of 0.5 meter, and the right panel displays estimates for communication distances of 1.0 meter. The vertical axes display the proportional likelihood of effective speech communication. The horizontal axes display the SRT in dB expressed in relation to the average threshold for otologically normal individuals. The four traces in each chart display the proportional likelihood of effective speech communication using normal, raised, loud, and shouted vocal effort as a function of SRT elevation.



Distance 0.5 meter

	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	1.00	0.96	0.90	0.85	0.79	0.72
Raised	1.00	0.98	0.96	0.94	0.92	0.89
Loud	1.00	1.00	0.99	0.99	0.98	0.96
Shouted	1.00	1.00	1.00	1.00	1.00	1.00

Distance 1.0 meter

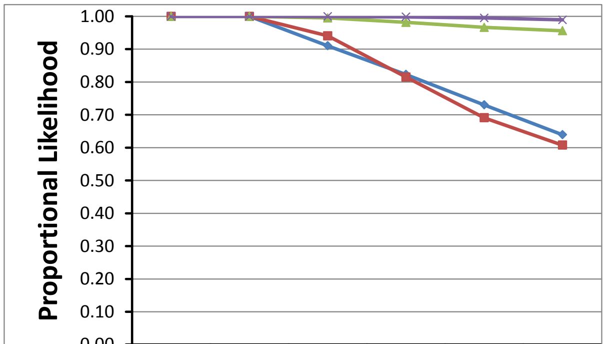
	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	1.00	0.92	0.83	0.75	0.68	0.62
Raised	1.00	0.96	0.92	0.87	0.82	0.76
Loud	1.00	0.98	0.97	0.95	0.93	0.90
Shouted	1.00	1.00	1.00	1.00	0.99	0.98

Figure 11: Estimates of Proportional Likelihood of Effective Speech Communication in Housing Locations

See Figure 10 caption for details.

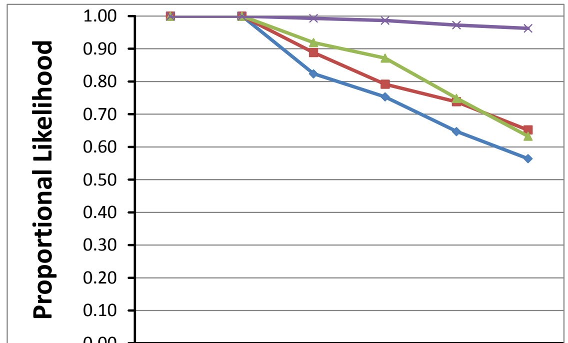
Figure 11 displays estimates of proportional likelihood of effective speech communication for only Housing locations in the same manner as in Figure 10. As stated above, 64% of incidents involving hearing took place in Housing locations, causing the ESII data set from Housing to receive a weight of 0.64. As with the absolute likelihood values, the pattern of proportional likelihood results for Housing and for the routine day are highly similar.

Distance 0.5 meter



	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	1.00	1.00	0.91	0.82	0.73	0.64
Raised	1.00	1.00	0.94	0.82	0.69	0.61
Loud	1.00	1.00	1.00	0.98	0.97	0.96
Shouted	1.00	1.00	1.00	1.00	1.00	0.99

Distance 1.0 meter



	0 dB	1 dB	2 dB	3 dB	4 dB	5 dB
Normal	1.00	1.00	0.82	0.75	0.65	0.56
Raised	1.00	1.00	0.89	0.79	0.74	0.65
Loud	1.00	1.00	0.92	0.87	0.75	0.63
Shouted	1.00	1.00	0.99	0.99	0.97	0.96

Figure 12: Estimates of Proportional Likelihood of Effective Speech Communication for Outdoor Recreation Locations
See Figure 10 caption for details.

Figure 12 displays the proportional likelihood estimates for Outdoor Recreation locations. The proportional likelihood data are more similar to the comparable data for Housing and for the routine day than are the absolute likelihood estimates. The absolute estimates exhibit substantially reduced values; however, these values are also reduced for otologically normal individuals, causing the proportional values to be calculated using much lower absolute values. The net effect is that the estimates of proportional likelihood of effective speech communication are fairly consistent for all three sets of analyses.

Discussion

These analyses provide a number of important insights as to how hearing impairment, as measured by elevated SRTs, affects the likelihood of effective speech communication throughout a Juvenile Corrections Officer's routine day. First, it is evident that even Juvenile Corrections Officers who are otologically normal are limited in the effectiveness of their speech communication because of background noise levels. This is true throughout the routine day, which is dominated by activities in Housing locations, and is especially so in the noisiest spots encountered during the routine day, such as Outdoor Recreation, Indoor Recreation, and Kitchen locations.

Second, because of the background noise levels, Juvenile Corrections Officers must use raised or loud vocal effort to ensure effective speech communication, except at the shortest communication distances. As communication distances increase, officers must rely on radios or other means of electronic communication.

Proportional likelihood measures are perhaps more important than absolute likelihood measures in evaluation of the effects of hearing loss on the ability to perform the hearing-critical job functions of a Juvenile Corrections Officer. These measures express the hearing impaired individual's ability to perform such functions relative to the abilities of otologically normal individuals. Thus, they do not directly reflect the difficulties that even individuals with normal hearing encounter in the high background noise environments found at times in juvenile detention facilities. However, when individuals with normal hearing encounter situations where the likelihood of effective communication is reduced substantially, even small additional reductions caused by hearing impairment may compromise safety and effectiveness by an unacceptable amount.

As SRTs become elevated due to hearing impairment, larger values of ESII are required for effective speech communication. The likelihoods for most levels of vocal effort decrease consistently with increasing SRT elevation, as compared with normally hearing individuals. For example, proportional likelihoods for raised or loud vocal effort drop below 0.90 in most of the analyses as SRTs increase. These considerations indicate that SRT elevation is a sensitive indicator of reduced likelihood of effective speech communication suitable for use in hearing screening.

HEARING GUIDELINES

Background

The data and analyses reported above that describe the effects of SRT elevation on the likelihood of effective speech communication throughout a Juvenile Corrections Officer's routine day indicate that normal vocal effort does not always result in effective speech communication, even at communication distances of 0.5 meter. Raised vocal effort is more effective at 0.5 meter distances, as are loud and shouted vocal effort at both distances.

These considerations indicate that SRT elevations having relatively small effects on the likelihood of effective speech communication should be used as screening criteria. This is because even individuals with normal SRTs do not have high likelihoods of effective speech communication in all noise environments in juvenile facilities. At the same time, however, the screening criteria cannot be so restrictive that individuals with normal hearing are excluded. Both of these considerations can be satisfactorily addressed by selecting screening criteria that do not exclude individuals with normal hearing and that result in only small reductions in the likelihood of effective speech communication.

Hearing screening of applicants and incumbents for jobs with hearing-critical tasks requires a measure of hearing impairment that is objectively related to the ability to perform these tasks. The Hearing in Noise Test (HINT) has been shown to provide such a measure. The HINT was initially developed as a general research and clinical tool to measure hearing impairment in a number of listening conditions that allow one to determine a subject's ability to understand and effectively communicate with speech in quiet and in noise. Listening conditions include measures of binaural ability, which are important for understanding speech in noise. The HINT Occupational Screener Technology (HOST) is a specialized adaptation of the general research and clinical tool used in the past. The HOST system is an effective and efficient method to screen applicants for Juvenile Corrections Officer[2] position.

Hearing Screening Protocol and Criteria

The Standards and Training for Corrections Hearing Guidelines specify two hearing screening criteria based on the HINT Composite Speech Reception Threshold (SRT) measured in noise and the SRT measured in quiet. The screening criterion defined by the Composite SRT in noise is based on the need for effective speech communication in the background noise environments where hearing-critical job functions are performed throughout a Juvenile Corrections Officer's routine day and during responses to incidents.

[2] Position titles vary among local jurisdictions and may include Juvenile Counselor, Group Supervisor, Juvenile Detention Officer, Probation Assistant, etc.

The screening criterion based on the SRT measured in quiet is based on the additional need to understand soft and whispered speech, as well as speech originating from behind doors or through windows.

The screening protocol consists of the Hearing in Noise Test administered in four test conditions, Quiet, Noise Front, Noise Right, and Noise Left. These test conditions are administered under headphones semi-automatically by the HINT Occupational Screener Technology (HOST). Testing can be done in a quiet room without visual distractions. The complete protocol can usually be administered in less than 20 minutes. Under all scenarios, devices that are used for testing will be run through a calibration procedure.

In each test a different list of 20 sentences is presented in random order in quiet or in the presence of a reference noise. For tests in noise the presentation level of the noise remains fixed at 65 dB (A), and the level of each sentence is adjusted automatically by the HOST, depending on whether the previous sentence was repeated correctly. The average presentation level of all sentences after the first four sentences defines the speech reception threshold for the test condition.

During a HINT test in noise, headphone signals for the left and right ears are processed to simulate the spatial location of the speech and noise sources. This simulation has been validated on multiple occasions. In the Noise Front condition, the speech and noise sources are co-located directly in front of the subject. In the Noise Right condition, the speech remains in front and the noise is located 90° to the right, and in the Noise Left condition, the speech remains in front and the noise is located 90° to the left.

The screening criterion for effective speech communication in noise is based on the elevation of the applicant's HINT Composite SRT above the average for otologically normal individuals. The average Composite SRT, expressed as a speech-to-noise ratio or SNR, is -6.4 dB SNR which defines the norm for individuals with normal hearing (Soli & Wong, 2008). The screening criterion is a HINT Composite SRT **of -4.0 dB SNR** or less. By placing the screening criterion at 2.4 dB SNR above the norm, over 99% of otologically normal individuals are expected to obtain passing scores. SRTs in noise are to be measured with the noise level fixed at **65 dB (A)**. The screening criterion for speech communication in noise may also be expressed as a HINT composite threshold of **61 dB (A)** or less. The preceding analyses indicate that a hearing impaired applicant who fails to meet this screening criterion is likely to have at least 15% less effective speech communication in noise throughout a typical workday as a Juvenile Corrections Officer, as compared with an otologically normal individual.

The hearing screening guideline for speech communication in quiet is based on the average level of soft or whispered speech heard at a short distance, 30 dB (A) (Nilsson, 1992;

Goldberg, 2001; Borden, 1984; Ostergaard, 1986). The hearing screening for speech communication in quiet is a HINT SRT in quiet of **27 dB (A)** or less. Over 99% of otologically normal individuals are also expected to obtain passing scores with this screening criterion.

An applicant who fails to meet either or both of the screening criteria may elect to be retested. Only the failed criteria need to be retested. Retesting should be done immediately after initial testing during the same visit. The illustration below displays a flowchart summarizing the retesting procedure. If the applicant fails again on the retest the applicant does not meet the guideline.

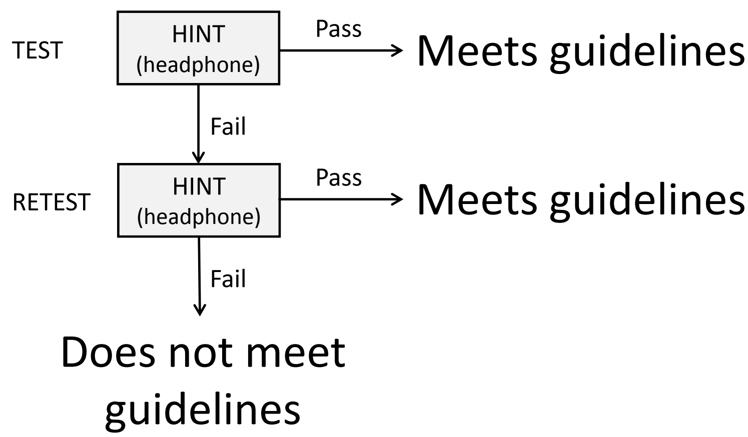


Figure 13: Screening Protocol – Test/Retest Procedure

Supplemental Screening Protocol for Applicants with Auditory Prostheses

Evaluation of Auditory Prostheses

An applicant for the job of Juvenile Corrections Officer may require the use of one or two auditory prostheses, such as hearing aids, to meet the hearing screening criteria established by the hearing guideline. In this case, it will be necessary for the individual to wear and use his or her prostheses at all times on the job.

Test Administration

Supplemental screening should be administered by an audiologist experienced with the type of auditory prostheses used by the applicant.

Sound Field Screening

Prior to administration of the HINT screening protocol, the audiologist must verify that the prostheses are functioning properly and adjusted to physiologically appropriate settings. Sound field HINT testing is done with the same protocol as headphone HINT testing. An applicant who meets both of the screening criteria during the initial sound field HINT tests meets the guideline. An applicant who fails to meet either or both of the screening criteria can be retested. If the applicant passes the retest the applicant has met the guideline. If the applicant fails again on the retest the applicant has not met the guideline.

Sound field testing must be conducted by an audiologist at a facility with a sound room large enough to conduct the screening protocol in the sound field. Again, the audiologist must verify that the prostheses are functioning properly and adjusted to physiologically appropriate settings. Evidence that the loudspeakers in the sound room have been calibrated within the last year and that the HINT norms have been appropriately adjusted for sound field testing must also be provided together with the printed report summarizing the test results.

The screening criterion for the sound field HINT are the same for the Quiet SRT, 27 dB (A) or less. However, the criterion for the composite SRT must be based on the *adjusted* sound field composite SRT, and not on the headphone composite SRT. This *adjusted* criterion is defined as the SNR 2.4 dB above the *adjusted* sound field composite HINT norm. The HINT test instrument automatically incorporates adjustments to the sound field norms after data have been input to achieve the appropriate adjustments.

The Hint Occupational Screener Technology (Host) System

As noted above, the HOST system is a specialized adaptation of the Hearing in Noise Test (HINT) for occupational screening. There are several features of this adaptation that are intended to make the HINT screening evaluations more portable, simpler, and more efficient, while ensuring the integrity of the data and test results used to make screening decisions. One of the advantages of the HOST system design is that it will enable users to minimize capital equipment costs at individual test facilities.

At the time of this report, the sole licensed distributor for the HOST system is Hearing Test Systems. Contact information is as follows:

HEARING TEST SYSTEMS
1395 Garden Highway, Suite 250
Sacramento, CA 95833
www.hearingtest.pro
jhart@hearingtest.pro
(916) 580-9644

Selecting Hint Testing Facilities

Should an agency wish to obtain HINT testing through a facility or vendor other than those served by HTS (above), the agency should ensure that the following criteria are met:

- The HINT screening is conducted for pre-employment screening, not clinical or diagnostic evaluations.
- The entity that administers the test uses the current version of HINT.
- The HINT instrumentation is calibrated correctly and maintained appropriately.
- Testing is conducted in accordance with HIPAA.
- Test reports are available to the hiring agency in a secure and controlled manner.
- Test administrators have been trained in the correct use of HINT for pre-employment screening and the STC Hearing Guidelines.

Appendix A: Bibliography

1. American Educational Research Association, American Psychological Association, & National Council on Measurement in Education. (1999). Standards for educational and psychological testing. Washington, D. C.

2. American National Standards Institute (2007). Methods for calculation of the speech intelligibility index. ANSI S3.5-1997 (Reaffirmed in 2007). New York: American National Standards Institute.

3. Barrenäs, ML, & Holgers, KM (2000). A clinical evaluation of the hearing disability and handicap scale in men with noise induced hearing loss. Noise & Health 6: 67-78.

4. Begines, T (1995) Fitness and risk evaluation. Spectrum 121:9–11. Cook LE, Hickey MJ. (2003) Physical hazards and noise in law enforcement. Clinical Occupational Environmental Medicine 3:419–442.

5. Bentler, RA (2000). List equivalency and test-retest reliability of the Speech in Noise test. American Journal of Audiology, 9(2):84-100.

6. Bilger, RC, Nuetzel, JM, Rabinowitz, WM & Rzeczkowski, C (1984). Standardization of a test of speech perception in noise. Journal of Speech and Hearing Research, 27:32-48.

7. Brannick, MT, Levine, EL., Morgeson, FP (2007). Job and work analysis. Thousand Oaks, CA: Sage Publications.

8. Bronkhorst, AW, & Plomp, R (1988). The effect of head-induced interaural time and level differences on speech intelligibility in noise. Journal of the Acoustical Society of America. 83(4):1508-16.

9. Bronkhorst, AW, & Plomp R, (1989). Binaural speech intelligibility in noise for hearing-impaired listeners. Journal of the Acoustical Society of America. 86(4):1374-83.

10. Bronkhorst, AW, & Plomp, R (1992). Effect of multiple speech like maskers on binaural speech recognition in normal and impaired hearing. Journal of the Acoustical Society of America. 92(6):3132-9.

11. Coles, RRA, and Sinclair, A (1988). Hearing. In Fitness for Work. The Medical Aspects. Edwards, FC, McCallum, RI & Taylor, PJ(eds). Oxford, Oxford University Press.

12. Cord, MT, Walden, BE, Atack, RM (1992). Speech recognition in noise test (SPRINT) for H-3 profile. Walter Reed Army Medical Center.

13. Cox, RM, Alexander, GC, Gilmore, C, & Pusakulich, KM (1988). Use of the Connected Speech Test (CST) with hearing-impaired listeners. Ear & Hearing, 9(4):198-207.

14. Dobie, RA, and Sakai, CS (2001). Estimation of hearing loss severity from the audiogram. In D Henderson, D Prasher, R Kopke, R Salvi, and R Hamernik (Eds.), Noise

induced hearing loss basic mechanisms, prevention and control. London, England: Noise Research Network Publications.

15. Duquesnoy, AJ, & Plomp, R (1983). The effect of a hearing aid on the speech-reception threshold of hearing-impaired listeners in quiet and in noise. Journal of the Acoustical Society of America 73(6): 2166-2173.

16. Duquesnoy, AJ (1983). Effects of a single interfering noise or speech source upon the binaural sentence intelligibility of aged persons, Journal of the Acoustical Society of America74, 739-743.

17. Festen, JM, & Plomp, R (1986). Speech-reception threshold in noise with one and two hearing aids. Journal of the Acoustical Society of America 79(2): 465-471.

18. Festen, JM, & Plomp, R (1990). Effects of fluctuating noise and interfering speech on the speech-reception threshold for impaired and normal hearing. Journal of the Acoustical Society of America. 88(4):1725-36.

19. Forshaw, S, & Hamilton, K (1997). Assessment of occupational hearing requirements. Canadian Acoustics 25: 3-9.

20. Forshaw, S, Ritmiller, R, Hodgson, M, Laroche, C, (1999) Estimates of speech intelligibility based on equivalent speech- and noise-spectrum levels and hearing thresholds. Canadian Acoustics 27: 112-113.

21. Giguère, C, Laroche, C, Soli, SD, and Vaillancourt, V (2008). Functionally-based screening criteria for hearing-critical jobs based on the Hearing In Noise Test. International Journal of Audiology, 47, 319-328.

22. Giguère, C, Laroche, C, Vaillancourt, V, Soli, SD (2010). Modeling speech intelligibility in the noisy workplace for normal-hearing and hearing-impaired listeners using hearing protectors. International Journal of Acoustics and Vibration 15: 156-167.

23. Goldberg, RL (2001). Hearing Guidelines for the California Commission on Peace Officer Standards and Training.

24. Guion, RM (1998). Assessment, measurement, and prediction for personnel decisions. Mahwah, NJ: Lawrence Erlbaum Associates.

25. Houtgast, T, & Festen, JM (2008). On the auditory and cognitive functions that may explain an individual's elevation of the speech reception threshold in noise. International Journal of Audiology 47:287-295.

26. Kales, SN, Aldrich, JM, Polyhronopoulos, GN, Artzerounian, D, Gassert, T, Hu, H, Kelsey, K, Sweet, C, Christiani, DC (1998). Fitness for duty evaluations in hazardous materials firefighters. Journal of Occupational and Environmental Medicine 40:925–931.

27. Kalikow, DN, Stevens, KN & Elliott, LL (1977). Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability. Journal of Acoustical Society of America, 61(5):1337-51.

28. Killion, M, & Niquette, PA (2000). What can the pure-tone audiogram tell us about a patient's SNR loss? Hearing Journal 53: 46-53.

29. Kramer, SE, Kapteyn, TS, Houtgast, T (2006). Occupational performance: comparing normally-hearing and hearing-impaired employees using the Amsterdam Checklist for Hearing and Work. International Journal of Audiology 45:503–512.

30. Laroche, C, Giguère, C, Soli, SD, Vaillancourt, V (2008). Establishment of fitness standards for hearing-critical jobs. In: Proceedings of the 9th Congress of the International Commission on the Biological Effects of Noise as a Public Health Problem, Mashantucket, CT. Dortmund, Germany.

31. Laroche, C, Giguère, C, Vaillancourt, V & Soli, SD (2005). Development and validation of hearing standards for Canadian Coast Guard Seagoing Personnel and C&P and land-based personnel. Phase II, Final report to Department of Fisheries and Oceans under Contract No. F7053-000009.

32. Laroche, C, Soli, SD, Giguère, C, Lagace´, J, Vaillancourt, V, Fortin, M (2003). An approach to the development of hearing standards for hearing-critical jobs. Noise and Health 6:17–37.

33. Laroche, C (1994). Cases of possible job discrimination based on hearing loss. Canadian Acoustics 22: 89-90.

34. MacLean, S (1995). Employment criteria in hearing critical jobs. Spectrum 12:20–23.

35. MacLean, S (2001). A practical approach to workplace communication assessment: or ''keep your head down and your ears open.'' NHCA Spectrum 18:12–13.

36. MacLean, S, Danielson, R (1996). Hearing standards in the U.S. military. Spectrum 13:16–17.

37. MacLean, S, Nilsson M (1997). Hearing critical jobs. Spectrum 14.

38. Middleweerd, MJ, Festen, JM, Plomp, R (1990). Difficulties with speech intelligibility in noise in spite of a normal pure-tone audiogram. Audiology 29:1–7.

39. Morata, TC, Themann, CL, Randolph, RF, Verbsky, BL, Byrne, DC, Reeves, ER (2005). Working in noise with a hearing loss: perceptions from workers, supervisors, and hearing conservation program managers. Ear & Hearing 26:529–545.

40. National Institute for Occupational Safety and Health (1998). Criteria for a recommended standard: Occupational noise exposure, Revised criteria 1998. Cincinnati, OH : Centers for Disease Control and Prevention.

41. Nilsson, M, Soli, SD, Sullivan, JA (1994). Development of the Hearing in Noise Test for the measurement of speech reception thresholds in quiet and in noise. Journal of the Acoustical Society of America 95:1085–1099.

42. Parving, A & Ostri, B (1983). On objective criteria for hearing impairment and hearing disability. Scandinavian Audiology 12: 165-169.

43. Pavlovic, CV, Studebaker, GA and Sherbecoe, RL (1986). An articulation index based procedure for predicting the speech recognition performance of hearing-impaired individuals. Journal of the Acoustical Society of America 80: 50-57.

44. Pearsons, KS, Bennett, RL & Fidell, S (1977). Speech Levels in Various Noise Environments. EPA-600/1-77-025, US Environmental Protection Agency.

45. Philippon, B, Giguere, C & Laroche, C (2004). Objective predictions of the performance intelligibility function for speech perception in different noise environments using the SII index. Technical report, Hearing Research Laboratory, University of Ottawa.

46. Plomp, R, & Mimpen, AM (1979). Speech-reception threshold for sentences as a function of age and noise level. Journal of the Acoustical Society of America. 66(5):1333-42.

47. Plomp, R (1978). Auditory handicap of hearing impairment and the limited benefit of hearing aids. Journal of the Acoustical Society of America 63:533–549.

48. Plomp, R, & Mimpen, AM (1979). Improving the reliability of testing the speech reception threshold for sentences. Audiology, 18:43-52.

49. Plomp, R (1986). A signal-to-noise ratio model for the speech-reception threshold of the hearing impaired. Journal of Speech and Hearing Research 29: 146-154.

50. Plomp, R, and Mimpen, AM (1981). Effects of the orientation of the speaker's head and the azimuth of a noise source on the speech-reception threshold for sentences. Acustica 48, 325-328.

51. Rhebergen, KS, Versfeld, NJ (2005). A speech intelligibility index-based approach to predict the speech reception threshold for sentences in fluctuating noise for normal-hearing listeners. Journal of the Acoustical Society of America 117:2181-92.

52. Rhebergen, RS, Versfeld, NJ & Dreschler, WA (2006). Extended speech intelligibility index for the prediction of the speech reception thresholds in fluctuating noise. Journal of the Acoustical Society of America 120:3988-3997.

53. Rhebergen, KS, Versfeld, NJ, Dreschler, WA (2008). Prediction of the intelligibility for speech in real-life background noises for subjects with normal hearing. Ear & Hear: 29 169-172.

54. Smoorenburg, GF (1992). Speech reception in quiet and in noisy conditions by individuals with noise-induced hearing loss in relation to their tone audiogram. Journal of the Acoustical Society of America 91:421-37.

55. Society for Industrial and Organizational Psychology (2003). Principles for the validation and use of personnel selection procedures. Bowling Green, OH

56. Soli, SD (2003). Hearing and job performance. Paper commissioned by the Committee on Disability Determination for Individuals with Hearing Impairment, National Research Council, National Academy of Sciences.

57. Soli, SD, & Vermiglio, A (1999). Assessment of functional hearing abilities for hearing-critical jobs in law enforcement. Report for the California Peace Officers Standards and Training Commission.

58. Soli, SD (2008). Some thoughts on communication handicap and hearing impairment. International Journal of Audiology, 47, 285-286.

59. Soli, SD, and Nilsson, MJ (1994). Assessment of communication handicap with the HINT, Hearing Instruments 45, 12-16.

60. Soli, SD, and Wong, L (2008). Assessment of speech intelligibility in noise with the Hearing In Noise Test. International Journal of Audiology, 47, 356-361.

61. Tufts, JB, Visal, KA, Briggs, S (2009). Auditory fitness for duty: A review. Journal of the American Academy of Audiology 20: 539-557.

62. U.S. Department of Labor. (2007) Medical examinations and inquiries specifically permitted. Regulations to implement the equal employment provisions of the Americans with Disabilities Act. 29 C.F.R. 1 1630.14. Washington, DC: U.S. Government Printing Office.

63. Vermiglio, AJ (2008). The American English Hearing In Noise Test. International Journal of Audiology, 47, 386-387.

Appendix B: Questions Posed to Panels of Subject Matter Experts

SME Question
Was the task speech or non-speech?
Speech Only Inquiries
Was the voice level at a whispered/softly spoken, normal, raised, or shouted level?
How much of the message did you understand?
Low- Did not hear enough of the message to figure it out
Medium- Understood the general idea of the message, but missed most of the details
High- Understood most of the message
Could the message be repeated?
Non-speech Only Inquiries
What did you know about the sound?
Detection- Heard something
Low- Uncertain (thought I heard something)
Medium- Moderately certain (heard something)
High- Certain (certain of what I heard)
Recognition- Heard and knew what I heard
Low- Uncertain (thought I heard something)
Medium- Moderately certain (heard something)
High- Certain (certain of what I heard)
Location- Knew where the sound came from
Low- Uncertain about the direction that the sound came from
Medium- Know the very general direction of where the sound came from
High- Know within a narrow margin the direction where the sound came from
Location and Recognition- Heard and knew where the sound came from
How loud was the sound? (Soft, Medium, or Loud)
How frequent was the sound? (Single, Continuous, or Intermittent)
Speech and Non-speech Inquiries
How far away (in feet) was the sound?
Was the sound source visible?
How loud was the background noise? (Quiet, Medium, or Loud)
What was your overall effort to hear? (Low, Medium, or High)

Appendix C: Supplemental Results From Subject Matter Expert Panels

Table C-1: Hearing of Speech vs. Non-Speech Sounds

Number and percent of hearing-critical job functions with speech communication and detection and recognition of non-speech sounds as functional hearing abilities.

Sound Type	Routine Day	Incident	Total	% of Total
Speech	23	7	30	44.1%
Non-Speech	19	19	38	55.9%
Total	42	26	68	100.0%

Table C-2: Vocal Effort

Vocal effort used to communicate with speech during a routine day and during responses to incidents.

Effort	Routine Day N=23	Incidents N=7
Whispered/Softly Spoken	30.4%	14.3%
Normal	34.8%	
Raised	34.8%	42.9%
Shout		42.9%

Table C-3: Repetition Opportunity

Opportunity to repeat speech communications during a routine day and during responses to incidents.

Repetition	Routine Day N=23	Incidents N=7
Yes	47.8%	71.4%
No	52.2%	28.6%

Table C-4: Estimated Background Noise Levels

Judged background noise levels while speech and non-speech functional hearing abilities were used during a routine day and during responses to incidents.

	Speech		Non-speech	
Noise Level	**Routine Day N=23**	**Incidents N=7**	**Routine Day N=19**	**Incidents N=19**
Quiet	34.8%	57.1%	26.3%	47.4%
Medium	30.4%	14.3%	52.6%	21.1%
Loud	34.8%	28.6%	21.1%	31.6%

Table C-5: Visibility of Sound Source

Visibility of sound source for routine days and incidents.

Visible	Routine Day N=42	Incidents N=26
Yes	28.6%	11.5%
No	71.4%	88.5%

Table C-6: Hearing Effort

Effort necessary to perform speech and non-speech functional hearing abilities during a routine day and during responses to incidents.

	Speech		Non-speech	
Hearing Effort	**Routine Day N=23**	**Incidents N=7**	**Routine Day N=19**	**Incidents N=19**
Low	43.5%	71.4%	47.4%	78.9%
Medium	26.1%	0.0%	47.4%	15.8%
High	30.4%	28.6%	5.3%	5.3%

Appendix D: Methodology for Making On-Site Calibrated Sound Recordings

All recordings were made using a hand-held digital audio recorder, the Edirol R-09HR manufactured by Roland. Recordings were made in stereo using the built in microphones on the device. The sampling rate was set to 44.1 kHz, and the sampling word length was set to 24 bits. According to the manufacturer's specifications, the microphones exhibit a uniform polar plot with directional variations in sensitivity of less than 3 dB. The manufacturer's specification also state that the microphone's frequency response is flat from 50 Hz up to 8 kHz, although this did not prove to be the case during calibration measurements. Recordings were stored on an SD memory card and later transferred to a personal computer for processing and analysis.

The field recordings from each location at each facility were manually edited to remove spoken comments by the individuals making the recordings and comments by Juvenile Corrections Officers and other detention staff. A free waveform editing software tool, Audacity (Version 1.2.6), was used to excise comments from each recording, leaving only the background noise for subsequent analysis. The remaining background noise often consisted of the voices of staff and detainees in addition to the sounds of equipment and other sounds typically present in those environments.

APPENDIX E: CALIBRATION PROCEDURES

Calibration of the recorder was done with the microphone sensitivity set to “high” and input gain set to “40,” which is midrange on a scale with a maximum setting of 80. Automatic gain control and compression features of the recorder were turned off at all times (the Edirol R-09HR is designed for recording live music, and thus is capable of sampling high sound pressure levels over a wide dynamic range). Calibration was performed using a Fonix 7000 Hearing Aid Analyzer manufactured by Frye Electronics. The recorder was turned on and placed in the Fonix test box. A 1 kHz pure tone was presented at 80 dB SPL and recorded for approximately 2 minutes. This recording was transferred to computer via the SD memory card, and its root mean square (RMS) level was calculated using Matlab. The RMS level expressed in dB corresponds to 80 dB SPL and to 80 dB (A), since dB SPL and dB (A) are equivalent at 1 kHz.

A second set of calibration recordings at different frequencies was made using the same procedure described above. Pure tones at 80 dB SPL were presented at 100 Hz intervals ranging from 100-1000 Hz and at 1000 Hz intervals ranging from 1000-8000 Hz (these are the intervals and frequencies that the Fonix system is capable of producing). The RMS values for these recordings revealed that the microphone frequency response was flat up to about 2 kHz, and then decreased by about 6 dB per octave up to 8 kHz.

The frequency-specific calibration recordings were used in two different ways. First, they provided the information necessary to convert RMS values to dB SPL for each of the 18 1/3 octave band filter outputs used to calculate SII and ESII. A total of 9 of the 18 center frequencies for these filters correspond to calibration frequencies measured with the Fonix system, with the lowest being 200 Hz and the highest 8000 Hz. Calibrations for the remaining 9 filter outputs were obtained by extrapolation.

The second use of the frequency-specific calibration recordings was to specify the frequency response for a modified A-weighted filter that could be used both to apply A-weighting and pre-emphasis to the recordings so that accurate L(eq) values could be calculated for each recording. L(eq) is expressed in dB (A) and is the long term RMS of the recording after A-weighted filtering. Use of a standard A-weighted filter to obtain the L(eq) for the current recordings would underestimate the true L(eq) because of the roll off in the frequency response of the microphone above 2 kHz. Thus, a modified A-weighted filter was designed with a frequency response matching the specifications for A-weighting up to 2 kHz. Above this frequency, 6 dB per octave of pre-emphasis was added to the specifications for A-weighting. Application of this pre-emphasis gain did not cause saturation in any of the recordings.

APPENDIX F: DETAILED SUMMARY OF SOUND RECORDINGS

A total of 124 recordings were made at the specified locations from the 28 facilities. The details describing these recordings are presented Table I-1. The recordings are organized according to location within the facilities. Within locations the recordings are grouped according to the rated capacity of the facility. Facilities with a rated capacity ≤ 60 are coded T1. Facilities with a rated capacity > 60 and ≤ 240 are coded T2, and facilities with a rated capacity > 240 are coded T3. The date and time of the recording and the facility where the recording was made are given in the left columns of the table.

The table also describes the general area where the recording was made (e.g., "control booth") and the specific location of the recording within the general area. The activity in progress at the time of the recording is also given. This information was noted on a recording log that was completed at the time of the recording.

The table also summarizes the research team's assessment of the characteristics of the noise, including its source, the distance of the source from the recording, and an estimate of the noise level. Also recorded was an estimate of the vocal effort used for speech communication by the Juvenile Corrections Officers. Raised or loud vocal effort was used for communication almost twice as often as normal vocal effort. The most common noise sources were the voices of the staff and detainees and the sounds associated with their activities. The distance of the noise from the recorder varied widely because in most cases there were multiple noise sources. The log keeper most often judged the level of the noise to be "moderate" or "loud."

It should be noted that the presence of the research team members with clipboards and recording instruments often had the effect of drawing the juveniles' attention and, in so doing, quieting their vocal activities. A number of the Juvenile Corrections Officer escorts observed that this was happening. Thus, the typical noise levels may actually be higher than those observed on some of the recordings.

The remaining entries in the table were generated at the time the recordings were processed. The duration is reported, as well as the L(eq), the long term RMS of the recording after it had been filtered with the modified A-weighting filter. L(eq) values were typically between 60 and 80 dB (A). In kitchen and recreation locations the L(eq) at times exceeded 80 dB (A). Finally, the number of ESII values calculated for each recording is given.

Table F-1: Background Noise Measurements – Summary Description of All Recordings

	Location Information			Information from Recordings						Information from Logs				
Nr	Activity	RC	Facility	Code	L(eq)	Samples	Date	Time	Dur	Location	Source	Dist	Level	Effort
1	Chow	T1	El Dorado JH	EJ3	64.6	174	13-Jul-11	1226	11.39	dining room entrance	key, talk, doors, trays, disposal	5-10 ft	L	N
2	Chow	T1	Humboldt JH	HJ5	61.2	53	21-Jun-11	1606	3.33	gym used as eating area	eating, talking, chairs	6-10 ft	L	N
					62.9	227			14.72					
3	Chow	T2	Fresno CF	RC6	61.0	75	30-Jun-11	1715	5.00	eating area in dayroom	food noise, talk, radio	6-20 ft	L	N-R
4	Chow	T2	Fresno CF	RC5	62.3	80	30-Jun-11	1704	5.21	eating area in dayroom	food noise, talk, radio	6-20 ft	L	N-R
5	Chow	T2	Kern JH	KJ2	76.7	60	9-May-11	1743	4.00	girls, cleanup after chow	chairs, talk, music	1-5 ft	M	N-R
6	Chow	T2	Kern JH	KJ1	61.5	91	9-May-11	1730	4.04	eating area in dayroom	radio, phone, talk, keys	2-15 ft	L-M	N
7	Chow	T2	LA Camp GR	LC4	73.6	48	6-Jun-11	1223	3.12	outside dining hall	entry to hall, fan noise	10-15 ft	H	R
8	Chow	T2	LA Camp GR	LC5	69.9	90	6-Jun-11	1152	6.19	near central control	prep for lunch, talk, commands	15 ft	M	R
9	Chow	T2	LA Camp GR	LC2	71.4	93	6-Jun-11	1247	6.13	inside occupied dining hall	serve lunch, talk	10-50 ft	L	N
10	Chow	T2	LA Camp GR	LC3	69.2	97	6-Jun-11	1235	6.29	inside occupied dining hall	serve lunch, talk	10-50 ft	L	N
11	Chow	T2	Orange Count YGC	YG1	77.2	106	22-Dec-11	702	7.07	dining room	voices, kitchen equipment	20	H	R
12	Chow	T2	Orange Count YGC	YG2	79.6	172	22-Dec-11	710	11.47	dining room	voices, kitchen equipment	20	H	R
13	Chow	T2	Orange County YLA	YA1	63.6	58	21-Dec-11	1132	3.87	dayroom	voices, lunch prep	60	L	N
14	Chow	T2	Orange County YLA	YA2	63.8	150	21-Dec-11	1148	10.00	dayroom	voices, lunch prep	60	L	N
					69.2	1120			72.39					
15	Chow	T3	Barry Nidorf JH	BN5	59.5	91	19-Dec-11	1712	6.07	housing unit	voices	15	L	N
16	Chow	T3	San Diego KMJDF	DK9	69.5	150	23-Jun-11	1643	10.01	out of rooms	dinner, talk, chairs, phones	2-20 ft	L-M	R
17	Chow	T3	Santa Clara JH	CJ1	71.0	170	25-Apr-11	1734	11.23	cafeteria, JCO spot	trays, talk, kitchen	5-35 ft	L	N
					66.7	411			27.31					
					66.2	1758			114.42					
18	Control	T1	Del Norte JH	NJ1	64.9	40	20-Jun-11	1339	2.40	control in pod	phone, talk, radio	2 ft	L	N
19	Control	T1	Del Norte JH	NJ4	60.2	52	20-Jun-11	1922	3.28	control in pod	radio, intercom, talk	5 ft	L	N
20	Control	T1	Lake JH	WJ1	63.4	76	22-Apr-11	1410	5.05	booth	phones, intercom, radio	5 ft	L	N
21	Control	T1	Placer JD	PJ1	68.8	122	10-May-11	948	8.11	control room	phone, chair, radio	2 ft	M	N
					64.3	290			18.84					
22	Control	T2	Alameda Camp WS	IS3	62.8	22	8-Jul-11	1146	1.29	central control	monitor, phone, music	3 ft	L	N
					62.8	22			1.29					
23	Control	T3	San Diego EMJD	DE5	64.6	57	24-Jun-11	1215	3.50	in control center	phone, talk, radio	2-10 ft	L	N
24	Control	T3	San Diego KMJDF	DK4	72.8	77	23-Jun-11	1551	5.11	courtyard control	basketball, talk, radio	5-30 ft	M	R
					68.7	134			8.61					
					65.3	446			29					

Table F-1: (continued)

Nr	Location Information			Information from Recordings						Information from Logs				
	Activity	RC	Facility	Code	L(eq)	Samples	Date	Time	Dur	Location	Source	Dist	Level	Effort
25	Housing	T1	Butte JH	UJ6	65.7	95	22-Apr-11	1114	6.21	staff station	doors, radio, talk	5-25 ft	L	N
26	Housing	T1	Butte JH	UJ4	68.8	169	22-Apr-11	1250	11.16	staff station	voices, radio, talk	5-20 ft	M	N-R
27	Housing	T1	Del Norte JH	NJ3	72.1	150	20-Jun-11	1907	10.02	dayroom	echoes, TV, talk	8 ft	M	R
28	Housing	T1	El Dorado JH	EJ5	58.4	76	13-Jul-11	1500	5.07	hallway entrance, girls	room time, talk, doors, radio	5-20 ft	L	N
29	Housing	T1	El Dorado JH	EJ4	66.8	121	13-Jul-11	1450	8.04	hallway entrance, boys	talk, doors, intercom	5-30 ft	M-H	R
30	Housing	T1	Humboldt JH	HJ1	66.6	54	21-Jun-11	1525	3.39	hallway with cells	talk, doors, intercom	3-10 ft	M	R
31	Housing	T1	Humboldt JH	HJ6	63.0	87	21-Jun-11	1613	5.48	dayroom program facility	eating, talking, chairs	3-6 ft	L	N
32	Housing	T1	Lake JH	WJ4	65.2	12	22-Apr-11	1426	0.49	by radio			L	N
33	Housing	T1	Lake JH	WJ3	62.3	47	22-Apr-11	1423	3.10	roving in halls	locked up, some showers	10-20 ft	L	N
34	Housing	T1	Merced JH	MJ2	69.3	129	19-Apr-11	1553	8.39	dayroom rec	TV, voices, phone	2-25 ft	M	R
35	Housing	T1	Merced JH	MJ3	68.8	150	19-Apr-11	1946	10.00	dayroom control area	TV, voices, phone	10-20 ft	M	R
36	Housing	T1	San Diego GRF	DG5	64.7	1	23-Jun-11	1133	0.00	dayroom living area	lunch, chairs, talk, carts	2-10 ft	L	N
37	Housing	T1	San Diego GRF	DG4	58.5	47	23-Jun-11	1129	3.08	dayroom living area	lunch, chairs, talk, carts	2-10 ft	L	N
38	Housing	T1	San Diego GRF	DG3	68.4	76	23-Jun-11	1117	5.07	living room in dorm	clean rooms, talk, phone	1-20 ft	M	N
39	Housing	T1	San Diego GRF	DG2	60.2	87	23-Jun-11	1101	5.48	chairs in dayroom	mediate, talk, phone	2-10 ft	L-M	N
40	Housing	T1	San Diego GRF	DG7	61.7	173	23-Jun-11	1658	11.34	dayroom	prep for dinner, talk, carts	1-25 ft	L-M	N
41	Housing	T1	San Diego GRF	DG6	64.0	191	23-Jun-11	1133	12.44	dayroom living area	lunch, chairs, talk, carts	2-10 ft	L	N
					65.0	1665			108.76					

Table F-1: (continued)

Nr	Location Information			Information from Recordings						Information from Logs				
	Activity	RC	Facility	Code	L(eq)	Samples	Date	Time	Dur	Location	Source	Dist	Level	Effort
42	Housing	T2	Fresno CF	RC4	70.8	96	30-Jun-11	1649	6.27	Central area in pod	open rec, ready for dinner, talk	5-20 ft	M	R
43	Housing	T2	Fresno CF	RC1	71.1	100	30-Jun-11	1619	6.43	open dayroom, boys	rec, talk, radio, yell	5-30 ft	M	R
44	Housing	T2	Fresno CF	RC2	68.4	111	30-Jun-11	1630	6.27	open dayroom, girls	rec, talk, radio, yell	5-30 ft	M	R
45	Housing	T2	Fresno JH	RJ3	63.5	64	30-Jun-11	1559	4.19	pod common area	open rec, talk, TV, doors	10-25 ft	L	N
46	Housing	T2	Fresno JH	RJ2	69.9	98	30-Jun-11	1546	6.32	JCO station, boys	open rec, talk, TV, doors	6-20 ft	L	N
47	Housing	T2	Fresno JH	RJ1	64.3	124	30-Jun-11	1535	8.19	JCO station, girls	open rec, talk, TV, doors	6-20 ft	L	N
48	Housing	T2	Kern Camp O	KC1	81.0	152	10-May-11	1932	10.08	dorm, open rec	games, phone, doors, talk	5-20 ft	H	R-S
49	Housing	T2	Kern JH	KJ3	68.6	91	9-May-11	1753	6.08	counter in dayroom	open rec, chairs, talk, laugh	1-5 ft	L-M	N
50	Housing	T2	Kern JH	KJ4	68.6	92	9-May-11	1821	6.04	table in dayroom	open rec, girls TV, talk, cards	4-10 ft	L-M	N-R
51	Housing	T2	LA Camp GR	LC6	73.0	94	6-Jun-11	1136	6.02	dining hall	lunch prep, talk	15 ft	L	N
52	Housing	T2	San Bernardino JDC	BJ5	66.4	77	6-Jul-11	1136	5.09	Dayroom	girls, lunch, toilets doors	5-15 ft	M	N
53	Housing	T2	San Bernardino JDC	BJ3	69.2	83	6-Jul-11	1113	5.33	Walk in dayroom	free time, TV, talk			
54	Housing	T2	San Bernardino JDC	BJ6	62.9	203	6-Jul-11	1144	13.33	Dayroom	boys, lunch, radio, keys, doors	5-15 ft		
55	Housing	T2	Solano JH	XJ1	75.0	158	10-Jul-11	1038	10.32	dayroom in pod	inside rec, TV, cart, calls, talk			
56	Housing	T2	Yolo JH	YJ1	73.5	77	9-Jul-11	1750	5.08	kids in rooms	simulation door pounding	20 ft	H	S
57	Housing	T2	Yolo JH	YJ2	71.4	169	9-Jul-11	1827	11.16	dayroom in pod	inside rec, kids at tables	10 ft	M	N
					69.9	1789			116.20					

Table F-1: (continued)

Nr	Location Information			Information from Recordings						Information from Logs				
	Activity	RC	Facility	Code	L(eq)	Samples	Date	Time	Dur	Location	Source	Dist	Level	Effort
58	Housing	T3	Alameda Sr JH	IJ4	78.2	34	8-Jul-11	932	2.16	hall near classroom	incident, loud talk, running	6-20 ft	H	S
59	Housing	T3	Alameda Sr JH	IJ2	66.4	58	8-Jul-11	909	3.53	dayroom as classroom	voices, talk	5-15 ft	M	N
60	Housing	T3	Alameda Sr JH	IJ1	66.2	164	8-Jul-11	853	10.56	dayroom	counseling, talk, phone	6-20 ft	M	N
61	Housing	T3	LA Centeral JH	LJ3	78.3	60	8-Jun-11	657	4.03	boys core unit	radio, talk, cleaning, toilets	5-60 ft	H	N-R
62	Housing	T3	Sacramento JH	JJ4	56.5	47	21-Jul-11	1654	3.11	common area	dinner, radio, talk, doors	10-25 ft	L	N
63	Housing	T3	Sacramento JH	JJ5	63.2	121	21-Jul-11	1712	8.06	dayroom	dinner, movement talking, cart	10-20 ft	M-L	R
64	Housing	T3	San Diego KMJDF	DK5	71.9	16	23-Jun-11	1610	1.07	dayroom	in and out of rooms, talk, doors	5-20 ft	M	R
65	Housing	T3	San Diego KMJDF	DK3	65.3	48	23-Jun-11	1542	3.14	dayroom	return from rec, voices, radio	5-20 ft	M	N
66	Housing	T3	San Diego KMJDF	DK6	65.4	75	23-Jun-11	1611	5.00	dayroom	in and out of rooms, talk, doors	5-20 ft	M	R
67	Housing	T3	San Diego KMJDF	DK1	68.6	86	23-Jun-11	1041	5.47	rooms in girls unit	crying, yelling, hit door, upset	2-5 ft	M	N-R
68	Housing	T3	San Diego KMJDF	DK8	69.4	99	23-Jun-11	1633	6.36	dayroom	set for dinner, talk, doors	3-20 ft	L-M	N
69	Housing	T3	Santa Clara JH	CJ6	73.1	17	25-Apr-11	1703	1.10	rec in dayroom	talk, TV, video games	2-10 Fft	M	N
70	Housing	T3	Santa Clara JH	CJ7	67.9	99	25-Apr-11	1705	6.38	rec in dayroom	talk, TV, video games	2-10 Fft	M	N
71	Housing	T3	Santa Clara JH	CJ5	73.6	113	25-Apr-11	1450	7.33	rec in dayroom	talk, TV, doors	2-10 ft	M-L	R
					68.9	1037			67.3					
					67.9	4491			292.26					
72	Indoor rec	T1	Del Norte JH	NJ2	75.4	77	20-Jun-11	1348	5.11	inside gym	group running	6-30 ft	H	S
73	Indoor rec	T1	Humboldt JH	HJ2	65.9	51	21-Jun-11	1532	3.24	indoor gym	basketball, TV	3-20 ft	M	R
74	Indoor rec	T1	Humboldt JH	HJ3	77.6	105	21-Jun-11	1541	7.00	indoor gym	basketball, TV	3-20 ft	M	R
75	Indoor rec	T1	Humboldt JH	HJ4	75.6	111	21-Jun-11	1552	7.25	indoor gym	basketball, TV	3-20 ft	M	R
					73.6	344			22.6					
76	Indoor rec	T3	Alameda Sr JH	IJ3	74.5	67	8-Jul-11	924	4.28	gym	exercise, games, talk, yell	4-25 ft	H	R
77	Indoor rec	T3	Alameda Sr JH	IJ5	85.8	97	8-Jul-11	945	6.31	gym	free activity ball bounce, talk	6-30 ft	H	S
78	Indoor rec	T3	Barry Nidorf JH	BN3	81.9	78	19-Dec-11	1520	5.20	Entrance to gym	sports activities, yelling	15	M	R
79	Indoor rec	T3	Sacramento JH	JJ3	72.4	122	21-Jul-11	1611	8.11	gym rec room	PE games, talk, clap	4-20 ft	M-H	R-S
80	Indoor rec	T3	Santa Clara JH	CJ4	71.5	62	25-Apr-11	1257	4.08	Bleachers in gym	loudspeaker, talk kids	25 ft	M	R
81	Indoor rec	T3	Santa Clara JH	CJ3	76.0	159	26-Apr-11	953	10.36	JCO spot in gym	exercise, volleyball, clapping	5-20 Ft	H	S
					77.0	585			38.34					
					75.3	929			60.94					

Table F-1: (continued)

Nr	Location Information			Information from Recordings						Information from Logs				
	Activity	RC	Facility	Code	L(eq)	Samples	Date	Time	Dur	Location	Source	Dist	Level	Effort
82	Kitchen	T1	Butte JH	UJ2	81.8	101	22-Apr-11	1208	6.47	dishing table	dish out lunch, trays, radio	2-5 ft		
83	Kitchen	T1	Butte JH	UJ1	83.2	110	22-Apr-11	1308	7.22	walk around	washing trays, cart, fan	5-20 ft	M	R
					82.5	211			13.69					
84	Kitchen	T2	LA Camp GR	LC7	78.5	90	6-Jun-11	1129	6.02	kitchen	lunch prep, talk	5-30 ft	M	R
85	Kitchen	T2	Orange Count YGC	YG3	83.2	80	22-Dec-11	722	5.33	dining room	kitchen equipment, cleanup	20	H	R
					80.85	170			11.35					
					81.7	381			25.04					
86	Medical	T2	San Bernardino JDC	BJ7	65.5	144	6-Jul-11	1202	9.38	Desk	phone, radio, doors	5-15 ft	L	N
					65.5	144			9.38					
87	Medical	T3	LA Centeral JH	LJ4	67.1	61	8-Jun-11	723	4.07	waiting room	voices, TV	3-15 ft	M	N
					67.1	61			4.07					
					66.3	205			13.5					
88	Movement	T1	Butte JH	UJ3	65.3	82	22-Apr-11	1146	5.29	from rooms to school	doors, radio, talk	2-15 ft	L	N
89	Movement	T1	El Dorado JH	EJ2	66.5	93	13-Jul-11	1220	6.13	multipurpose room	release for lunch, keys, talk			
90	Movement	T1	Lake JH	WJ2	53.7	33	22-Apr-11	1418	2.12	housing corridor	kids in rooms			
					61.8	208			13.54					
91	Movement	T2	San Bernardino JDC	BJ4	62.4	81	6-Jul-11	1129	5.26	Dayroom	girls return from school	5-15 ft	L	N
					62.4	81			5.26					
92	Movement	T3	Los Pedrinos JH	LP3	74.5	82	20-Dec-11	741	5.47	hallway near holding cell	voices	5	H	R
93	Movement	T3	Santa Clara JH	CJ2	69.5	178	26-Apr-11	913	11.53	court waiting area	talk, phones	3-20 ft	L	N
					72.0	260			17.00					
					65.4	549			35.80					

Table F-1: (continued)

Nr	Location Information			Information from Recordings						Information from Logs				
	Activity	RC	Facility	Code	L(eq)	Samples	Date	Time	Dur	Location	Source	Dist	Level	Effort
94	Outdoor rec	T1	Butte JH	UJ6	76.2	80	22-Apr-11	1045	5.23	Gym, volleyball	Voices, balls	5-20 ft	M	R
95	Outdoor rec	T1	El Dorado JH	EJ6	71.9	150	13-Jul-11	1507	10.02	middle of rec area	exercise, talk, radio	5-30 ft	M	N-R
96	Outdoor rec	T1	El Dorado JH	EJ1	75.6	158	13-Jul-11	1039	10.35	walk around	boy and girl PE, talk, balls	5-20 ft	M	N-R
97	Outdoor rec	T1	San Diego GRF	DG1	65.6	71	23-Jun-11	1055	4.45	outside courtyard	helicopter, talk, sports	15-20 ft	L	N
					72.3	459			30.05					
98	Outdoor rec	T2	Alameda Camp WS	IS1	74.5	96	8-Jul-11	1050	6.25	outside yard	free time, bouncing balls	6-20 ft	M	R
99	Outdoor rec	T2	Fresno CF	RC3	65.7	80	30-Jun-11	1640	5.23	grassy playground	football, radio, shout	15-40 ft	M	R
100	Outdoor rec	T2	San Bernardino JDC	BJ1	71.0	77	6-Jul-11	1106	5.10	middle of rec area	outdoor sports	5-15 ft	M	N, R
					70.4	253			16.58					
101	Outdoor rec	T3	Barry Nidorf JH	BN4	79.9	76	19-Dec-11	1526	5.07	Outdoor cement court	dodgeball, yelling	10	H	S
102	Outdoor rec	T3	Barry Nidorf JH	BN2	66.5	90	19-Dec-11	1510	6.00	Outdoor rec, soccer	voices, yelling	20	L	N
103	Outdoor rec	T3	Barry Nidorf JH	BN1	61.6	117	19-Dec-11	1502	7.80	Outdoor rec, soccer	voices, yelling	20	L	N
104	Outdoor rec	T3	Orange County JH	OJ2	75.9	79	21-Dec-11	1517	5.27	outdoor fitness cage	voices, sports activity		M	R
105	Outdoor rec	T3	Orange County JH	OJ3	70.8	82	21-Dec-11	1532	5.47	entrance to dayroom	TV, voices, phone		M	R
106	Outdoor rec	T3	Orange County JH	OJ1	75.2	91	21-Dec-11	1504	6.07	outdoor fitness cage	voices, sports activity		M	R
107	Outdoor rec	T3	Sacramento JH	JJ2	74.7	61	21-Jul-11	1644	4.05	courtyard young kids	volleyball, whistles, voices	2-20 ft	M	R
108	Outdoor rec	T3	Sacramento JH	JJ1	72.6	64	21-Jul-11	1536	4.19	courtyard	volleyball, voices	2-20 ft	M	R
109	Outdoor rec	T3	San Diego KMJDF	DK2	72.8	77	23-Jun-11	1534	5.09	blacktop	exercise, car, yelliing	10-25 ft	M	R
110	Outdoor rec	T3	San Diego KMJDF	DK7	59.7	82	23-Jun-11	1618	5.29	courtyard	exercise, keys, voices, radio	10-30 ft		
					71.0	819			54.30					
					71.2	1531			100.93					

Table F-1: (continued)

Nr	Location Information			Information from Recordings						Information from Logs				
	Activity	RC	Facility	Code	L(eq)	Samples	Date	Time	Dur	Location	Source	Dist	Level	Effort
111	Receiving	T1	Placer JD	PJ2	65.8	83	10-May-11	937	5.35	intake doorway	talk, keys, doors	5-10 ft	M	N
					65.8	83			5.35					
112	Receiving	T3	LA Centeral JH	LJ5	72.7	179	8-Jun-11	736	11.58	linear corridor, holding room	voices, staff, TV	2-60 ft	M-H	N-R
113	Receiving	T3	Los Pedrinos JH	LP2	70.6	95	20-Dec-11	733	6.33	intake area	voices	5	M	R
114	Receiving	T3	Los Pedrinos JH	LP1	70.5	100	20-Dec-11	726	6.67	intake area	voices	5	M	R
					71.3	374			24.58					
					68.5	457			29.93					
115	School	T1	Lake JH	WJ5	61.7	31	22-Apr-11	1432	2.04	classroom	teacher instructing	10-30 ft	L	N
116	School	T1	Placer JD	PJ3	68.7	94	10-May-11	1002	6.19	max security room	talk, doors, chairs	5-20 ft	M	N
117	School	T1	Placer JD	PJ4	71.1	120	10-May-11	1018	8.02	by desk	watching music, talk, radio	5-20 ft	M	N
					67.2	245			16.25					
118	School	T2	Alameda Camp WS	IS2	69.1	113	8-Jul-11	1110	7.35	classroom	talk, pencil sharpener	10-20 ft	M	N
119	School	T2	LA Camp GR	LC1	70.1	92	6-Jun-11	1416	6.08	classroom	teacher student talk, radio	10-20 ft	M	N
					69.6	205			13.43					
120	School	T3	Alameda Sr JH	IJ6	71.3	98	8-Jul-11	959	6.33	housing classroom	break, minor incident	6-20 ft	M	N
121	School	T3	LA Centeral JH	LJ2	64.0	61	8-Jun-11	850	4.04	traditional classroom	teacher voice, reading aloud	2-15 ft	L-M	N
122	School	T3	LA Centeral JH	LJ1	66.0	75	8-Jun-11	843	5.00	traditional classroom	teacher voice, reading aloud	2-15 ft	L-M	N
					67.1	234			15.37					
					68.0	684			45.05					
123	Visiting	T2	San Bernardino JDC	BJ9	69.5	215	6-Jul-11	1429	14.21	by lobby door	talk, babies, movement			
124	Visiting	T2	San Bernardino JDC	BJ8	67.8	233	6-Jul-11	1343	15.32	Lobby	shift change, doors, talk	5-10 ft	M	N
					68.7	448			29.53					
					68.7	448			29.53					

APPENDIX G: RATIONALE FOR SPECIFICATION OF CRITICAL VALUE FOR THE EXTENDED SPEECH INTELLIGIBILITY INDEX

To describe the process by which criterion ESII values are defined and applied, it is first necessary to consider the relationship between HINT SRTs, ESII, speech intelligibility, and the likelihood of effective speech communication in complex, fluctuating background noise environments. HINT SRTs were related to ESII (and SII) values by applying the 18 1/3-octave filter band analysis to the reference stationary HINT noise scaled to correspond to a sound pressure level of 65 dB(A), the presentation level used during testing. The filter outputs for the HINT noise were converted to spectrum levels and combined with the standard speech spectrum levels for normal vocal effort and the band importance function for "short passages of easy reading material" (ANSI S3.5-1997, 2007) to obtain the SII. Note that the standard also specifies 62.35 dB SPL as the standard speech spectrum level for normal vocal effort.

The SII for the HINT noise under these assumptions is 0.34. The HINT Noise Front condition most closely approximates the assumptions used for the SII calculation. The norm for individuals with normal speech communication ability in this condition is an SRT of 62.4 dB (A), closely approximating the standard speech spectrum level for normal vocal effort, and the SII at the Noise Front norm is 0.35. Thus, the ability of the SII to predict the Noise Front SRT for individuals with normal speech communication ability is evident. Note also that other investigators have found that the SII at the SRT to be approximately 0.34 (e.g., Houtgast & Festen, 2008).

The speech spectrum levels and band importance functions used to calculate the SII and ESII for the HINT Noise Front threshold are those reported in the standard short passages of easy reading materials produced with normal vocal effort (Tables 3 and B.2 in ANSI S3.5-1977, 2007). These speech spectrum levels from the standard for normal vocal effort (62.35 dB SPL at 1 meter) can be compared with the speech spectrum levels of the HINT sentences at the Noise Front threshold (62.4 dB(A) at 1 meter). The average spectrum level difference across the 18 1/3-octave bands was 0.98 dB, with the HINT speech spectrum levels slightly higher. More importantly the average spectrum level difference for the range of 1/3 octave bands from 315-3150 Hz, which contribute 82% of the overall band importance, was only 0.02 dB, with the spectrum levels in the standard slightly higher. These data indicate there are small differences in the HINT and ANSII spectrum levels at the extremes of the frequency range for the 1/3-octave band filters; however, the impact of these differences on the ESII calculations and the hearing screening standard is anticipated to be minimal because of the very close agreement in spectrum in the mid frequency regions where band importance is greatest for speech intelligibility.

Speech intelligibility, measured as the percent of words correctly recognized from all sentences, is approximately 70% at the HINT SRT for Noise Front and for the other HINT test conditions as well (Nilsson et al., 1994; Vermiglio, 2008). The slope of the function relating percent intelligibility to presentation level for levels near the SRT is 10%/dB (Soli & Wong, 2008). Thus, increasing the presentation level by 3 dB from 62.4 dB (A) to 65.4 dB (A) should result in 100% intelligibility. The SII (and ESII) at this presentation level is 0.45, which corresponds exactly to the value given as the minimum SII for acceptable intelligibility (ANSI S3.5-1997, 2007).

Neither the SII nor the ESII adequately consider listening conditions in which speech and noise sources originate from different locations. In these conditions the binaural auditory system allows one to listen selectively and improve the SRT, as discussed above. The effects of the binaural auditory system are considered by use of the HINT Composite threshold. The Composite HINT threshold equally weights the best- and worst-case listening scenarios to provide an overall estimate of the SRT across a variety of listening conditions. The published norm for the Composite SRT is 58.6 dB (A) (Soli & Wong, 2008; Vermiglio, 2008). The ESII corresponding to this level is approximately 0.25, or 0.10 units lower than the value calculated under the assumptions in the standard. These considerations suggest that the minimum ESII and SII for acceptable intelligibility is also 0.10 units lower than the value stated in the guideline, or 0.35 instead of 0.45, when best- and worst-case listening conditions are given equal consideration.

Another consideration is that effective speech communication, especially in situations where the utterances can be repeated, does not necessarily require 100% intelligibility, that is, an ESII of 0.35. For example, if an ESII corresponding to 80% intelligibility is specified, this means that 80% of the time communication is effective and 20% of the time it is not. If communication is not effective and the utterance is repeated, the likelihood that the repetition will also not be effective is also 20%, assuming the two attempted communications are independent—a conservative assumption. Thus, the joint probability that both communications will be ineffective is the product of the two probabilities of ineffective communication, or 0.20 X 0.20 = 0.04, and the probability of an effective communication after one repetition is 1.00 – 0.04 = 0.96; thus, when a single repetition is allowed nearly perfect communication can occur when the likelihood of effective speech communication without repetition is 0.80.

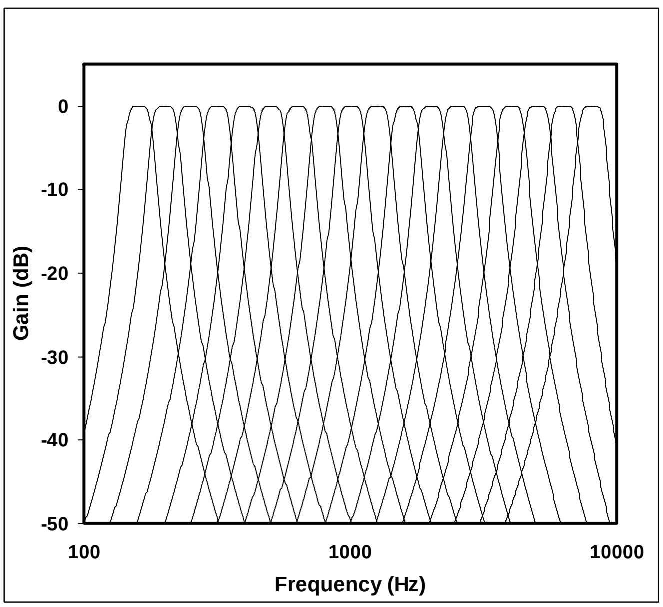
The ESII corresponding to 80% intelligibility under worst-case conditions is 0.40. If the prior reasoning that weights best- and worst-case scenarios equally is applied, the ESII value for effective speech communication is reduced by 0.10 to 0.30. Thus, an ESII of 0.30 can serve as a conservative criterion for evaluation of the 16 cumulative frequency distributions associated with each location to determine the proportion of 4-second intervals in which the ESII exceeds the criterion value. This proportion defines the likelihood of effective speech communication in the background noise environments associated with each location. In summary, these analyses can define the likelihood that Juvenile Corrections Officers with normal speech communication ability working in these locations encounter background noise environments allowing effective speech communication while performing the hearing-critical job functions of a normal work day.

Appendix H: Method for Calculation of the Extended Speech Intelligibility Index

Preparation of ESII Data Sets

The SII and ESII are based on the band importance function for speech (ANSI 3.5-1997, 2007). The band importance functions specify for different frequency bands the relative importance of speech information contained in the band. The standard for calculating SII also specifies the standard speech spectrum level in each band as a function of vocal effort, which is defined as either normal, raised, loud, or shouted. The spectrum level of speech information in a band in relation to the spectrum level of noise in the same band, together with the band importance of the speech information, is used to calculate the SII. Thus, it is essential to determine the spectrum level of the noise for each band. This is done by filtering the noise recordings into a number of frequency bands. The standard specifies that one such method of filtering is to use 18 1/3 octave band filters with center frequencies ranging from 160 Hz to 8000 Hz with equal logarithmic spacing.

A 1/3 octave band filter set was designed using a Matlab program developed by Courvreur (1997). This program designs fractional octave band filters, that is, 1/3 octave band, according to specifications in ANSI S1.1-1986. The frequency responses of the 18 filters used in the current analyses are show in the figure below. Note that all of the filters exhibit unity gain in their pass band, which is important for the use of the RMS-to-dB calibration for each band.



Frequency responses of 18 1/3 octave band filter set used to process background noise recordings for ESII calculations.

The SII does not specify the duration of the time interval over which the spectrum level of the noise in each band is to be calculated, since it assumes the noise is stationary. However, the ESII makes no such assumptions. It specifies precisely the duration for each of the 18 frequency-dependent time windows, with the windows for the lowest frequency band having the longest duration (35 ms) and the windows for the highest frequency band having the shortest duration (9.4 ms; Rhebergen & Versfeld, 2005). These windows are aligned at their offsets and are spaced every 9.4 ms, the duration of the shortest time window. This means that the windows for low frequency bands overlap substantially.

A Matlab program was written to filter each recording with the 18 1/3 octave band filters. Rectangular frequency-dependent time windows were applied to the 18 filtered time waveforms every 9.4 ms, and the RMS level for each window was calculated. This process produced slightly more than one hundred RMS values per second of recording for each of the 18 1/3 octave band filter outputs. These RMS values were converted to band levels expressed in dB SPL using the calibration information for each band described above. Next, the noise band levels were converted to noise spectrum levels by applying the bandwidth adjustment values given in Table 3 of the standard (ANSI 3.5-1997, 2007).

The noise spectrum levels for the 18 bands, expressed every 9.4 ms, together with the speech spectrum levels and the band importance function for short passages of easy material from the standard (ANSI 3.5-1997, 2007), were used to calculate slightly more than 100 SII values per second of recorded background noise. These calculations were performed with a series of Matlab programs developed by Muesch (2005) and posted on the web page for the standard (www.sii.to). The ESII specifies that these "snapshot" SII values be averaged over the time interval of interest to obtain a single estimate of the ESII for that interval (Rhebergen & Versfeld, 2005). Rather than use the entire duration of the recording as the interval of interest, it is more appropriate to define a shorter interval during which a typical brief two-way communication might occur. This interval was specified as 4 seconds Thus, the average ESII was calculated for all 4-second intervals in each recording. There are 435 SII snapshots in each 4-second interval that contribute to the average. Note that these intervals are not exactly 4 seconds in duration because there is no integer multiple of 9.4 ms whose product is exactly 4 seconds.

The ESII calculation process described in the preceding paragraph was repeated 16 times for the data from each location, using the four levels of vocal effort specified in the standard (normal, raised, loud, and shouted) and four communication distances (0.5 m, 1 m, 5 m, and 10 m).

The final step in processing the 16 ESII data sets from each location was to cast each data set into cumulative frequency distributions. Once in this form, it was possible to determine the proportion of 4-second intervals in which the ESII exceeded a specified criterion value for each level of vocal effort and each communication distance. The ESII step size for the frequency distributions was set at 0.03, which is the change in ESII corresponding to 1 dB change in SRT for an audiometrically normal individual.

Appendix I: Local Juvenile Detention Facilities that Participated in the Research

Facility	Incident Reports	SME Panel Interviews	Individual SME Interviews	Background Noise Measurement
Alameda County Juvenile Justice Center	X		X	X
Alameda County Camp Wilmont Sweeney	X	X		X
Butte County Juvenile Hall				X
Contra Costa County Orin Allen Youth Rehabilitation		X		
Del Norte County Juvenile Hall				X
El Dorado County Juvenile Hall				X
Fresno County Juvenile Justice Campus	X			X
Fresno County Juvenile Justice Commitment Facility				X
Glenn County Jane Hahn Juvenile Hall			X	
Humboldt County Juvenile Hall	X			X
Imperial County Juvenile Hall	X		X	
Kern County James G. Bowles Juvenile Hall				X
Kern County Juvenile Camp Erwin Owen				X
Kings County Juvenile Center	X			
Lake County Juvenile Hall				X
Los Angeles County Barry Nidorf Juvenile Hall				X
Los Angeles County Camp Rockey				X
Los Angeles County Central Juvenile Hall	X			X
Los Angeles County Los Padrinos Juvenile Hall				X
Madera County Juvenile Detention Facility			X	
Marin County Juvenile Hall			X	
Mendocino County Juvenile Hall	X			
Merced County Juvenile Justice Corrections Complex				X
Napa County Juvenile Justice Center			X	
Nevada County Carl F. Bryan II Juvenile Hall			X	
Orange County Juvenile Hall	X			X

Facility	Incident Reports	SME Panel Interviews	Individual SME Interviews	Background Noise Measurement
Orange County Youth Guidance Center				X
Orange County Youth Leadership Academy				X
Placer County Juvenile Detention Facility				X
Riverside County Juvenile Hall	X			
Sacramento County Youth Detention Facility	X	X		X
San Benito County Juvenile Hall			X	
San Bernardino County Ctrl Juvenile Det/Assessment Ctr	X			X
San Diego County East Mesa Juvenile Hall	X			X
San Diego County Girls' Rehabilitation Facility				X
San Diego County Kearney Mesa Juvenile Hall			X	X
San Joaquin County Juvenile Hall	X	X		
San Luis Obispo County Juvenile Hall	X			
San Mateo County Camp Glennwood		X		
San Mateo County Youth Services Center	X			
Santa Barbara County Juvenile Hall	X			
Santa Barbara County Los Prietos Boys Camp			X	
Santa Clara County William F. James Boys Ranch		X		
Santa Clara County Juvenile Hall				X
Shasta County Crystal Creek Regional Boys Camp	X			
Siskiyou County Charlie Byrd Youth Corrections Center			X	
Solano County Juvenile Detention Facility	X	X		X
Stanislaus County Juvenile Hall			X	
Tehama County Detention Facility			X	
Tulare County Detention Facility			X	
Ventura County Juvenile Facilities-Detention Services	X		X	
Ventura County Juvenile Facilities-Commitment Services			X	
Yolo County Juvenile Detention Facility	X	X		X