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Fit for the frontline? Identification of mission-critical auditory tasks (MCATs) carried out by infantry and combat-support personnel

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Abstract

The ability to listen to commands in noisy environments and understand acoustic signals, while maintaining situational awareness, is an important skill for military personnel and can be critical for mission success. Seventeen auditory tasks carried out by British infantry and combat-support personnel were identified through a series of focus groups conducted by Bevis *et al.* For military personnel, these auditory tasks are termed mission-critical auditory tasks (MCATs) if they are carried out in a military-specific environment and have a negative consequence when performed below a specified level. A questionnaire study was conducted to find out which of the auditory tasks identified by Bevis *et al.* satisfy the characteristics of an MCAT. Seventy-nine British infantry and combat-support personnel from four regiments across the South of England participated. For each auditory task participants indicated: 1) the consequences of poor performance on the task, 2) who performs the task, and 3) how frequently the task is carried out. The data were analysed to determine which tasks are carried out by which personnel, which have the most negative consequences when performed poorly, and which are performed the most frequently. This resulted in a list of 9 MCATs (7 speech communication tasks, 1 sound localization task, and 1 sound detection task) that should be prioritised for representation in a measure of auditory fitness for duty (AFFD) for these personnel. Incorporating MCATs in AFFD measures will help to ensure that personnel have the necessary auditory skills for safe and effective deployment on operational duties.

Keywords: Auditory fitness for duty, communication, hearing loss, military, mission critical auditory tasks

Introduction

Situational awareness describes an individual's awareness of what is happening around them and the relative importance of this information.^[1] It is not difficult to imagine a scenario in which situational awareness is of utmost importance for military personnel. For example, during a battle scenario military personnel may be listening to instructions over a radio, operating a weapon system, and detecting the enemy's location while needing to be fully aware of their surroundings. Endsley^[1] proposed a theory that suggests three levels of situational awareness. These can be summarized as:

1. gathering information,
2. understanding the information, and
3. giving meaning to the information.

Situational awareness can be affected by one or more factors such as attention level, tiredness, stress, workload, experience, and, of particular interest here, impaired sensory modalities, such as hearing loss. One element of the information-gathering stage of situational awareness is picking up auditory cues. In a military operation, auditory information can be vital during the first level of situational awareness; not only is a great deal of information passed over radio communication systems but personnel also utilize environmental sounds to gain a detailed picture of their surroundings. This becomes particularly important when cues from other sensory modalities are obscured, for example when buildings or vehicles block the line of sight. In these situations the use of auditory cues to remain operationally effective is of utmost importance.^[2]

Due to the nature of their work and the equipment they use, military personnel are regularly exposed to unsafe levels

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of noise^[3] and this puts them at high risk of noise-induced hearing loss (NIHL).^[4] Personnel may also be affected by other common causes of hearing loss such as presbycusis, genetic hearing loss, and conductive hearing loss (caused by infection, a build-up of wax, or a perforated ear drum). Hearing-impaired personnel perceive fewer of the auditory signals available to them, compromising the information gathered during the first stage of situational awareness.

The phrase auditory fitness for duty (AFFD) was first introduced by Tufts *et al.*^[5] and refers to the possession of sufficient hearing abilities for safe and effective job performance.^[5] It therefore follows that an AFFD test should assess performance based on the hearing-dependent tasks carried out within a given occupation. When referring to non-military occupations these hearing-dependent tasks are commonly termed hearing-critical tasks.^[5,6] The novel phrase mission-critical auditory tasks (MCATs) is being introduced in this paper to encompass hearing critical tasks carried out in a military specific environment.

A task is deemed to be hearing critical if a decrease in performance is observed when hearing-impaired individuals carry out the task.^[6] Tufts *et al.*^[5] modified this definition to also consider the consequences of poor performance, defining hearing-critical tasks as “tasks for which hearing loss would be a liability in inexperienced workers.” To satisfy the definition given by Tufts *et al.*^[5] there must be negative consequences if a task is conducted below certain performance levels. “Inexperienced workers” refers to individuals who are unable to use past experience to increase their performance on a task.

In this study the definition of an MCAT incorporates the definitions of hearing-critical tasks given by Laroche *et al.*^[6] and Tufts *et al.*,^[5] combining hearing dependency, performance level and consequences of poor performance, specifically addressing the critical component of MCATs. Therefore, an MCAT must satisfy two criteria:

1. It must be hearing-dependent and
2. Failure to perform the tasks to a specified level will result in decreased safety, efficiency, and/or operational effectiveness.

Although a large number of organizations (such as the police, fire service, coast guard, and air traffic control) use some form of AFFD protocol,^[5] very few of these organizations have adapted their hearing assessment measures to specifically address whether or not employees are capable of carrying out job-specific hearing-critical tasks. Employment criteria should be directly related to whether individuals are able to carry out their jobs safely, effectively, and efficiently. Therefore, outcome scores from AFFD measures should be capable of predicting, to a known level of accuracy, the corresponding performance level on hearing critical tasks.

The current measure of AFFD used during British military medical examinations is pure tone audiometry (PTA). By

using this test, which assesses ability to hear pure tones at different frequencies in quiet, a relationship is assumed between pure tone thresholds and performance on MCATs. It is reported in the literature that pure tone thresholds cannot be used to accurately predict performance levels in complex listening environments.^[7,8] It is therefore proposed that a new measure of AFFD be developed for the British military that will be able to predict, to a known level of accuracy, performance on MCATs.

In order to develop this new AFFD measure, it is necessary to first identify the MCATs conducted by military personnel. Through content analysis of focus group interviews with infantry and combat-support personnel, Bevis *et al.*^[9] produced a list of 17 auditory tasks carried out by personnel on operational duties listed in Table 1. These tasks can be split into three themes: Speech communication, sound detection, and sound localization. Although this list of tasks provides information about the complex auditory environments British infantry personnel are working in, it is not possible to use the qualitative data alone to identify MCATs. Further information is needed about each task in order to determine which of the auditory tasks satisfy the criteria of an MCAT.

The first characteristic of an MCAT is hearing dependency. It was judged by the primary author of the present study that all 17 auditory tasks identified in the focus groups^[9] cannot be carried out using job experience or other sensory modalities, alone and are therefore hearing-dependent. The second characteristic of an MCAT is that failure to perform the task to a specified level will result in decreased safety, efficiency, and/or operational effectiveness. To determine whether an auditory task

Table 1: List of hearing-dependent tasks arising from the focus group study of Bevis *et al.*^[9]

Speech communication
T1: Accurately hearing commands in a casualty situation
T2: Accurately hearing grid references
T3: Accurately hearing directions on patrol
T4: Accurately hearing directions in a vehicle
T5: Accurately hearing fire control orders
T6: Accurately hearing “stop” commands
T7: Accurately hearing the briefing before a foot patrol
T8: Communicating accurately through an interpreter
Sound localization
T9: Locating a small arms firing point
T10: Locating artillery firing point
T11: Locating the moving sound source of a motorbike
T12: Locating the moving sound source of enemy footsteps
T13: Locating rustling of vegetation and leaves
T14: Locating a person talking
Sound detection
T15: Identifying the type of weapon systems being fired
T16: Identifying talker identity
T17: Detecting a malfunction of an item of machinery

meets this criterion, knowledge of the consequences of poor performance is needed.

Following the identification of MCATs, a measure of auditory fitness can be created or adapted to represent all or a selection of these tasks. Representing a task does not imply that an exact replication of the MCAT should be included as part of the AFFD test battery, but infers that the auditory skills personnel require to carry out the task should be assessed. Measures of AFFD should accurately assess performance on hearing-critical tasks and should be generally applicable to the majority of employees within a given occupation. In a military context, a suitable AFFD test battery needs to include performance measures that are appropriate for the majority of ranks and roles. A compromise is needed to accurately measure auditory fitness on specific tasks without creating a test battery that is only valid for a small proportion of personnel. By documenting who performs the MCATs and how frequently, any tasks that are seldom carried out or those performed by small numbers of personnel are highlighted. These tasks do not need to be prioritized for representation in a measure of AFFD.

To summarise, three pieces of information about each auditory task are required in order to determine which of the tasks are mission-critical, and which should be represented by a measure of AFFD:

1. The consequences of poor performance on the task,
2. Which ranks and roles perform the task, and
3. How frequently the task is performed.

For this study, one-to-one interviews, focus groups, and questionnaires were considered as data collection techniques. One-to-one interviews or focus groups with infantry and combat-support personnel (as used by Bevis *et al.*)^[9] can be used to explore participants' thoughts and opinions in detail, and to discover areas of agreement and disagreement.^[10] However, these methods typically produce unstructured data, which (for the purpose of this study) would need to be organized, coded, and quantified, and are also prone to researcher bias. Questionnaires, conversely, do not allow for such detailed exploration, but can provide more readily quantifiable data.

A questionnaire approach was adopted by Brown and Fallowfield^[11] in their work on developing a strength-based Royal Navy fitness test. They first created a list of strength-based tasks performed aboard Royal Navy ships through consultation with subject matter experts and then used a questionnaire approach, with Likert-type scales to collect information about the strength demands, importance and frequency of each task. This produced quantifiable data that were used to identify the most critically-demanding generic tasks performed aboard Royal Navy ships. The authors in the present study adopted this style of questionnaire.

Aims

The present study aimed to identify which of the auditory tasks carried out by infantry and combat-support personnel can be defined as MCATs, and which MCATs should be represented by a measure of AFFD. Note that this work focuses on the MCATs carried out by infantry and combat-support personnel and therefore the findings cannot be generalised to the whole of the Armed Forces.

Methods

The list of tasks included in the questionnaire was taken directly from the focus group results of Bevis *et al.*^[9] listed in Table 1. For each of the 17 auditory tasks, participants were required to give Likert scale ratings concerning:

1. The significance of the consequences of poor performance,
2. Whether the task is carried out by all, some or no infantry personnel, and
3. How frequently the task is performed during a training exercise or when serving on a tour of duty.

The questionnaire was developed in consultation with subject matter experts at the Institute of Naval Medicine (INM), Gosport.

The response options for the “consequences of poor performance” and “frequency of task” questions were based on the scales used for assessing the risk of events on generic risk assessment documents.^[11] To determine the consequence of poor performance, the consequence scale used in the University of Southampton Risk Estimation Matrix^[12] was used. For the question relating to frequency of task performance, the corresponding scale in the Royal Navy physical strength questionnaire^[13] was used. Response options for who performs each task were limited to “all,” “some,” or “no infantry personnel.” If the participant selected “some” they were asked to indicate which roles carried out that particular auditory task. The options for each question are shown in Table 2. Due to the range of auditory tasks it was not possible to provide descriptions for response answers (for example, what is meant by “minor consequence”) that would be applicable to all tasks. Participants were therefore not given guidance on how to interpret the answers to each question.

Participants were recruited from 4 regiments across the South of England. The questionnaire and a covering letter outlining the study were sent via email to 11 senior personnel who had been involved in the focus group study;^[9] seven responded and four responded positively. Four regiments completed the questionnaire, resulting in a total of 87 questionnaire responses (regiment 1, $n = 34$; regiment 2, $n = 16$; regiment 3, $n = 23$; regiment 4, $n = 14$).

Table 2: Survey guide

Consequences of poor performance	WHO performs this task?	Frequency of task
In your opinion how significant are the consequences of poor performance on this task?	In your opinion, during a training exercise or when serving on a tour of duty is this task carried out by all infantry personnel, some infantry personnel or no infantry personnel?	In your opinion, how frequently is this task performed during a training exercise or when serving on a tour of duty?
1 = No Consequence	1 = No infantry personnel	1 = Seldom or yearly
2 = Minor	2 = Some infantry personnel (indicate which roles)	2 = Occasionally or monthly
3 = Moderate	3 = All infantry personnel	3 = Regularly or weekly
4 = Major		4 = Frequently or daily
5 = Critical		5 = Continuously or several times per day

The senior personnel were tasked with recruiting groups of infantry personnel, regardless of rank or role, resulting in an opportunistic sampling approach. The researcher requested that the senior personnel distribute the participant information sheet and consent forms 24 h before data collection, giving participants opportunity to withdraw from the study if they wished. The questionnaires for one regiment were distributed and collected by the first author. For the remaining three regiments, senior personnel distributed and collected the questionnaires, and forwarded them to the first author.

Data collection took place at the participants' normal place of work. Prior to giving consent and completing the questionnaire it was reiterated that participation was voluntary and that personnel could withdraw at any time without giving a reason. Consent forms were not attached to the questionnaires, ensuring that all responses were anonymous. In total, 87 questionnaires were completed and 79 were used for analysis. Reasons for questionnaire exclusion were: Incomplete questionnaire ($n = 4$); incorrect use of scale, for example answering "4" when the options were numbered 1-3 ($n = 3$); and giving the same answer for every question indicative of the instructions not being followed ($n = 1$).

Within Regiment Four a small group of participants ($n = 8$) were asked to complete the questionnaire a second time five days later to collect data on the repeatability of the questionnaire. The participants were each given a number to write on both of their questionnaires, making it possible to link the data while ensuring anonymity. This group was selected using opportunistic sampling; only participants that would be available to fill in the questionnaire on both dates were selected.

Ethical considerations

Ethical approval was obtained for this study from the University of Southampton and Ministry of Defence (MoD) Research Ethical Committee (Ref: 359/GEN/12). All data collected were anonymous and treated confidentially.

Participants

All participants had experience of an infantry or combat-support role, either during training exercises or during an operational tour of duty and represented a wide range of ranks and roles. Participant details are given in Table 3.

Table 3: Participant information

Characteristics	Number of participants n (%)
Gender	
Male	78 (99)
Female	1 (1)
Time serving in the armed forces (completed years)	
Mean (min/max)	8 (1/27)
Rank	
Private	36 (45)
Lance corporal	10 (13)
Corporal	12 (15)
Sergeant	10 (13)
Warrant officer	1 (1)
Lieutenant	3 (4)
Captain	5 (6)
Major	2 (3)
No. of tours of duty	
0	12
1	25
2	16
3	8
≥ 4	18
Tour locations	
Afghanistan	94
Northern Ireland	11
Iraq	29
Macedonia	1
Bosnia	14
Cyprus	2
Kosovo	7
Falklands	1
Not stated	23

Results

The results from all participants were pooled and are reported as median values or as a proportion of all responses. The data gathered from the Likert-type scale data are ordinal and therefore the median is the most appropriate measure of central tendency.^[14]

Consequences of poor performance

Table 4 shows the proportion of responses for each consequence rating with the median rating shaded black. For all the speech communication tasks (T1-T8) the majority of the responses (>68%) indicated that poor performance would

result in a critical or major consequence, with very few participants rating the tasks as having less than a moderate consequence. For the sound localization tasks only T9, T10, and T12 received the majority of responses (>65%) for the critical or major consequence categories. For the sound detection tasks, only T15 was rated as having critical or major consequence by the majority of participants (53%). For all the tasks the median consequence score is above 3 (moderate consequence); this may be a result of response bias and is considered further in the Discussion section.

Table 4 shows that there was a large variation in the responses to the question about negative consequences from poor performance. For all of the tasks, a few participants ($\leq 5\%$) responded with “no consequence.” This may be due to participants not reading the question or scale correctly or misinterpretation of the question, as opposed to a genuine belief that poor performance on a task would have no negative consequence. For example, it seems unlikely that personnel would suggest there would be no consequences if directions on a foot patrol were not accurately heard; yet 2.5% of participants responded with this answer. This is covered further in the Discussion section.

Despite a few personnel responding “no consequence,” for all the tasks there is a general consensus amongst

participants that there is some consequence of poor performance, with the majority of responses ($\geq 95\%$) within the range of minor to critical consequence. Therefore, it can be concluded that all 17 auditory tasks can be considered ‘mission-critical’.

Roles that carry out each task

The majority of participants responded that all infantry personnel are expected to carry out every task, as shown in Table 5. The median result for each task, apart from one, was a score of 3, indicating that there was a general agreement between participating personnel that these tasks are carried out by all personnel. Only T8, communicating accurately through an interpreter, had a lower median score of 2 (interquartile range = 1) (carried out by some infantry personnel); for this reason it was not deemed necessary to represent T8 in a measure of AFFD for infantry and combat-support personnel.

If the participants answered “some infantry personnel” for any task they were asked to indicate which roles carried out the task. Tasks T2, T4, and T8 gained the highest number of responses for only some infantry personnel carrying out the tasks. The roles that were said to carry out each of these tasks are listed in Table 6; it is apparent that a number of different roles perform each task.

Table 4: Percentage of responses for each task for each consequence rating

Consequences of poor performance	Task (proportion of responses, %)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
No consequence (1)	1	0	3	0	1	0	2	3	3	2	3	1	4	4	3	2	5
Minor consequence (2)	1	2	4	4	2	1	0	0	0	6	25	6	20	14	5	25	15
Moderate consequence (3)	7	13	25	24	10	7	18	24	11	27	33	18	40	38	39	37	33
Major consequence (4)	14	37	25	35	22	27	34	43	25	22	23	29	18	23	34	27	28
Critical consequence (5)	77	48	43	37	65	65	46	30	61	43	16	46	18	21	19	9	19

The shaded black section shows the median rating. Each column totals 100%

Table 5: Percentage of responses for each task for the question ‘who performs this task’

Who performs the task	Task (proportion of responses, %)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
No infantry personnel (1)	5	4	4	3	3	3	4	6	3	4	3	3	6	3	3	10	13
Some infantry personnel (2)	14	33	9	39	19	10	10	46	5	11	6	6	3	6	10	19	10
All infantry personnel (3)	81	63	87	58	78	87	86	48	92	85	91	91	91	91	87	71	77

The shaded black section shows the median rating. Each column totals 100%

Table 6: Infantry personnel reported to perform tasks 2, 4 and 8; the three tasks with the highest number of responses for ‘some infantry personnel’

Task 2 Accurately hearing grid references (33% of responses for “some infantry personnel”)	Task 4 Accurately hearing directions in a vehicle (39% of responses for “some infantry personnel”)	Task 8 Communicating accurately through an interpreter (46% of responses for “some infantry personnel”)
Those in command (23)	Those who drive vehicles (14)	Those in command (29)
Those who communicate over radio (2)	Those in command (12)	Interpreters (4)
Point man (1)	Gunners (5)	Ground personnel only (1)
Signaller (1)	Those in vehicle mounted regiments (4)	
	Fire Support Groups (1)	
	Dismounted Commander (1)	

Number in brackets indicates the number of responses given for each role

While the majority of participants answered that some or all infantry personnel carry out all tasks, there were a small number ($\leq 13\%$ for any given task) that responded with “no infantry personnel.” It is surprising that these participants responded in this manner given that the majority of tasks seem pivotal to the infantry role, for example “accurately hearing directions on a foot patrol.” This raises concern that some participants were not clear about the meaning of the question; this is addressed in the Discussion section.

Frequency of task performance

Table 7 shows the proportion of responses for each frequency rating with the median values shaded black. None of the tasks had a median frequency rating of 5 (continuously or several times per day). Five tasks (T2, T3, T4, T5, and T7) had a median frequency rating of 4 (frequently or daily); these were all speech communication tasks. For all tasks apart from two (T10 and T17), the majority of responses ($>50\%$) indicate that the tasks are carried out “regularly or weekly,” or more frequently.

Surprisingly, 5% of participants responded that accurately hearing grid references was a task carried out seldom or yearly when the majority responded that this task was continuously or several times per day. This result may mean that some participants were answering the questionnaire based upon their individual role within the infantry as opposed to the infantry as a whole.

Identifying tasks to be represented by a measure of AFFD for infantry personnel

To determine which tasks are most important for an AFFD measure, the tasks were arranged in a consequence/frequency matrix. They have been positioned according to their median consequence and frequency score [Figure 1].

There is no definitive way to combine these two pieces of data since no previous research has been conducted in this area. Grey-scale classification has been used to represent the importance of the task being represented in an AFFD assessment. The tasks in the black area are those that should be prioritised. The tasks in the grey and white areas are performed less frequently and/or have lesser consequences, causing them to be of lower priority.

Figures 2 and 3 show the percentage of participants whose responses agree with the matrix [Figure 1]. The error bars show the 95% confidence intervals of the participant's responses for the two consequence rating groups (see key on Figure 2) and the two frequency rating groups (see key Figure 3). Figure 2 shows that the majority of personnel (over 70% across all tasks) stated that there would be at least a moderate consequence for all tasks if performed poorly. The large gap between the two consequence groupings suggests that participants were in agreement about the consequence of poor performance on each task. Figure 3 shows that for all the tasks that fall in the black area of the matrix [Figure 1], the

Table 7: Percentage of responses for each for each frequency rating

Frequency of task performance	Task (proportion of responses, %)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Seldom or yearly (1)	7	5	6	4	3	4	6	17	6	32	9	18	14	10	9	20	21
Occasionally or monthly (2)	35	15	14	11	24	26	20	15	24	27	32	32	30	23	20	29	35
Regularly or weekly (3)	38	17	9	24	23	30	17	21	24	23	30	29	27	27	39	23	24
Frequently or daily (4)	14	24	26	26	26	17	36	24	29	11	20	17	21	17	26	12	14
Continuously or several times per day (5)	6	39	45	35	24	23	21	23	17	7	9	4	8	23	6	16	6

The shaded black section shows the median rating. Each column totals 100%

Consequences of poor performance					
	No consequence	Minor	Moderate	Major	Critical
Frequency of task performance	Seldom or yearly				
	Occasionally or monthly		T17 ^s	T10 ⁻ T12 ⁻	
	Regularly or weekly		T11 ⁻ T13 ⁻ T14 ⁻ T16 ^s	T15 ^s	T1 ⁺ T6 ⁺ T9 ⁺
	Frequently or daily			T2 ⁺ T3 ⁺ T4 ⁺ T7 ⁺	T5 ⁺
	Continuously or several times per day				

Figure 1: Consequence/frequency matrix. (Key ^sspeech communication, ⁻sound localization, ⁺sound detection), numbers relate to tasks in Table 1

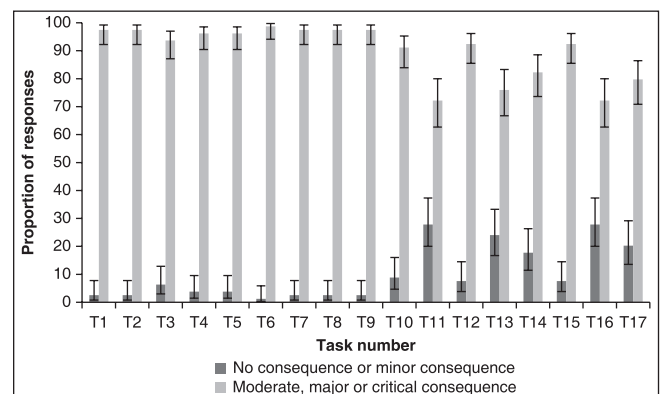


Figure 2: Percentage of responses for no/minor consequence if the task is performed poorly and moderate/major/critical consequence if the task is performed poorly. Error bars show 95% confidence intervals

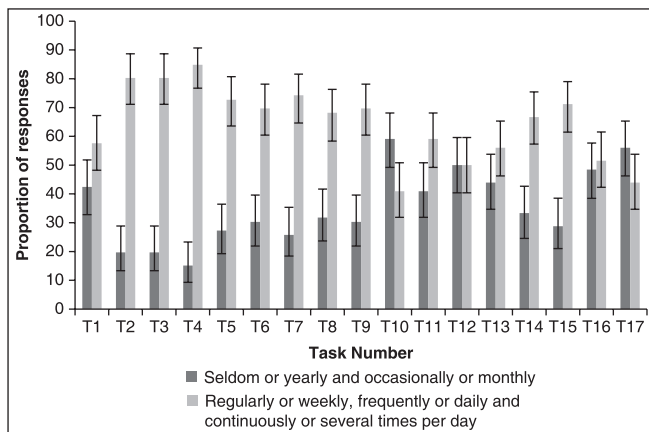


Figure 3: Percentage of responses for tasks performed seldom or yearly/occasionally or monthly and those performed regularly or weekly/frequently or daily/continuously or several times per day. Error bars show 95% confidence intervals

majority of personnel (over 55% across all tasks) stated that these tasks are carried out at least regularly or weekly.

Using this matrix approach assumes that the consequence and frequency ratings have equal weighting (a task carried out regularly or weekly with major consequence falls in the same category as a task carried out frequently or daily with moderate consequence). There is one area of the matrix where this assumption may be problematic. Firstly, tasks carried out seldom or yearly with critical consequence should arguably fall into the black area; personnel should be able to carry out any task that has critical consequence, even if they are rarely required to perform it. Although this is an important consideration when using a risk matrix, during the present study no tasks fell within this area.

The decision to place the cut off point for inclusion in a measure of AFFD between the grey and black area is arbitrary. This point was chosen in order to include the tasks with moderate/major/critical consequence if the task is performed poorly, and tasks performed regularly or weekly/frequently or daily/continuously or several times per day. By using the matrix in Figure 1 it is possible to generate a list of MCATs that should be prioritized for representation in a measure of AFFD for infantry personnel and those in combat-support roles; these are listed in Table 8.

Test-retest reliability

In order to estimate the repeat-reliability of the questionnaire a sample of the participants ($n = 8$) completed the questionnaire twice. The participants were all from regiment 4. For each participant the responses were summated across each of the questions (consequences, who and frequency). This resulted in 6 values for each participant representing their responses to each question, on the two questionnaires. Since the data were measured on a Likert-type scale, the Spearman's rank-order correlation was selected to measure the strength

Table 8: List of MCATs to be prioritised for representation in a measure of AFFD for infantry personnel

Speech communication

- T1: Accurately hearing commands in a casualty situation
- T2: Accurately hearing grid references
- T3: Accurately hearing directions on patrol
- T4: Accurately hearing directions in a vehicle
- T5: Accurately hearing fire control orders
- T6: Accurately hearing "stop" commands
- T7: Accurately hearing the briefing before a foot patrol

Sound localization

- T9: Locating a small arms firing point

Sound detection

- T15: Identifying the type of weapon systems being fired

of association between the repeated questionnaires. There was a positive correlation between responses on the two completed questionnaires, which was statistically significant ($r_s(22) = .803, P = <.001$). The absolute difference between responses on the questionnaire repeats was calculated. Across the 8 participants, the average absolute difference in ratings between questionnaire repeats was a change of less than one rating for all the questions (0.6 for the consequences of poor performance, 0.3 for who performs each task and 0.7 for the frequency of task performance).

Discussion

The primary aim of this study was to identify MCATs for infantry and combat-support personnel; the secondary aim was to determine which MCATs should ideally be represented by a test of AFFD. A list of 17 auditory tasks carried out by infantry personnel and combat-support roles were taken from the focus group study carried out by Bevis *et al.*^[9] and were further investigated using a questionnaire. Each task was rated with regards to the consequences of poor performance, who carries out the task and the frequency of task performance.

Identifying MCATs

All 17 of the tasks from the Bevis *et al.*^[9] study can be considered MCATs; they are all hearing dependent and poor performance could result in a significant negative consequence. Distinguishing between "significant consequence of poor performance" and "non-significant consequence of poor performance" is subjective and for this reason, a cut-off was not used. However, from Table 1 it can be seen that none of the tasks were rated by the majority of participants as having no consequences to poor performance. It is assumed that any consequence could have a negative impact on the safety, efficiency and/or effectiveness of the task in question. Therefore, all 17 tasks can be classed as MCATs.

Prioritising MCATs for representation in a measure of AFFD

It has been established that a measure of AFFD should be based on job-specific tasks^[5,6] and in a military specific

context this means basing an AFFD test on MCATs. All of the MCATs identified in the present study are eligible for inclusion when designing a measure of AFFD for infantry personnel. It is not proposed that a measure of AFFD includes exact replicas of the tasks that are performed in the MCATs identified. For example performance on the task “accurately hearing the briefing before a foot patrol” does not necessarily have to be assessed by replicating the task itself. The idea is to assess the types of auditory skills needed to perform well in that environment, such as hearing speech in the presence of background noise or being able to localise a sound source.

In order for a task to be prioritised for representation by a measure of AFFD that is applicable for the majority of roles and responsibilities, it is first important to establish that the task is carried out by the majority of infantry personnel. The data from question 2 (“Who performs this task?”) were used to exclude tasks that were only carried out by specific roles. Only one task (T8, communicating accurately through an interpreter) was found to be carried out by some, as opposed to all, infantry personnel and was therefore excluded from further consideration.

The final stage of the analysis involved identifying the tasks that are performed frequently and have significant consequences when performed poorly. Tasks that are performed infrequently and/or have minor consequences to poor performance were considered as having low priority for representation in a measure of AFFD. The results in Figure 1 show that only one of the tasks (T17, detecting a malfunction of an item of machinery) falls within the white area, indicating low frequency of performance and minor consequences of poor performance. By only incorporating tasks that fall into the black area of the frequency/consequence matrix [Figure 1] the AFFD measure will represent the tasks that are performed most frequently and have the most significant effect on the safety and effectiveness of a mission.

Question interpretation and variation in responses

Tables 4 and 7 display the variation in participant responses for the consequence and frequency data. They show that there is a large variation in the answers given for the questions about frequency and consequence. However, for the all tasks that fall within the black area of Figure 1 the majority of participants responded that the tasks have moderate to severe consequence (ranging from 92% of responses for T15 to 99% of responses for T6) and are carried out regularly or weekly to continuously or several times per day (ranging from 58% of responses for T1 to 85% of responses for T4).

For all three questions there were some unexpected responses from a small number of participants, which may be due to misinterpretation of the questions. It seems unlikely that a participant would state that ‘no infantry personnel are required to accurately hear directions on a foot patrol’ since this is an integral part of being an infantry soldier, yet

3.8% of participants gave this response. Similar unexpected responses were given for the consequence and frequency questions. For example, 2.5% of participants answered that there are no consequences when a small arms firing point is not located (or located incorrectly; T9) and 4.5% responded that accurately hearing grid references (T2) is a task carried out seldom or yearly. These unexpected responses call into question how participants interpreted the questionnaire. It could be that some individuals were answering based solely on their role within the armed forces, rather than considering the general role of an infantry soldier. For an individual who has only been serving for a short time period or has not yet been on a tour of duty it is possible that they do not have sufficient experience to call upon. They may not have experienced the consequences of poor performance on a task, or may not perform certain tasks as part of their role, causing these individuals to answer that there is no consequence if the task is poorly performed or that the task is rarely performed. The questionnaire was intended to yield information about the infantry workforce in its entirety, not about individual roles or experiences.

It is not known if the order of the questions had any influence on the data obtained. It is possible that participants’ views on what each scale item meant to them evolved as they filled out the questionnaire, causing their opinions to change when answering questions towards the end of the questionnaire in comparison to the beginning.^[15]

Individual decision criteria could have varied between participants, particularly when answering the consequence question. It is possible that one participant considered the injury of a colleague as a ‘critical’ consequence, whereas another participant may not consider the situation critical until there is loss of life. This may account for the variation in participant responses for this question.

Finally, the phrasing of the question regarding the significance of consequences of poor performance could be interpreted to imply that the task is not inconsequential. Participants could, therefore have been discouraged from selecting option one, “no consequence,” and possibly even option two, “minor consequence,” resulting in a response bias.

Application of findings

The final list of MCATs [Table 8] includes all three types of auditory task: Speech communication, sound localization, and sound detection. These findings are consistent with those of Tufts *et al.*^[15] who recognised that an AFFD test battery should include measures of functional hearing ability including speech understanding, sound localization, sound detection and recognition. The end result of this questionnaire is an objective, evidence-based list, characterizing the most important tasks to be represented by a measure of AFFD for infantry personnel. This is the first step towards developing a measure of AFFD based on the jobs carried out by infantry

and combat-support personnel. There are auditory tests that measure performance on these aspects of hearing ability, such as speech threshold testing and sound source identification tasks. However, there are currently no auditory tests used by the UK military that have been validated to measure AFFD.

Research has been conducted to develop and validate measures of AFFD for other occupations. Giguère *et al.*^[16] investigated whether speech communication performance (on hearing critical tasks in the Department of Fisheries and Oceans) could be predicted using the Hearing in Noise Test^[17] (HINT), a speech recognition test. They used statistical modelling to relate scores on the HINT to performance on occupational auditory tasks. This information was then used to predict individual performances on various tasks from their HINT score. Work has also been carried out to develop validated tools to measure other aspects of fitness for duty, such as physical fitness. Approaches to developing objective physical standards for the military, police, fire, and emergency services that are based on tasks identified through a job analysis have been explored by Payne and Harvey^[18] and Tipton *et al.*^[19] Aspects of the physical fitness measures used by the UK military have been reviewed to assess whether the test criteria are fair, valid and justifiable for assessing fitness for duty.^[13,20]

Having completed the job analysis stage of AFFD test development, the second stage will involve identifying, developing, and validating auditory tests. This second step will be achieved by:

1. Developing simulations of the MCATs,
2. Measuring whether personnel are actually able to carry out the task using their hearing,
3. Determining whether the MCATs are sensitive to hearing loss, and
4. Exploring which clinical tests are able to predict performance on the MCATs.

For the sound localization and sound detection MCATs, there is currently sparse literature assessing whether personnel are in fact able to carry out these tasks using their hearing. Initially, simulations of these MCATs will be used to determine the performance levels of normal hearing personnel. For example, for the sound localization MCAT, a source identification task using recorded gunfire will be used to measure normal hearing personnel's ability to detect the source of small arms fire. For the speech communication MCATs it can be assumed that personnel are able to do these tasks using their hearing and that performance on the tasks is sensitive to hearing loss, particularly high frequency hearing loss that is commonly associated with high levels of noise exposure.^[4] Considering this, a measure of speech recognition will be selected and its suitability as an AFFD measure evaluated. This measure must be shown to accurately predict performance on a range of simulated speech communication MCATs.

As the focus groups and questionnaire were carried out using participants recruited from the infantry (Army and Royal Marines) and combat-support roles, the results from this study cannot be generalised to the wider Army, Royal Air Force, or Royal Navy. While the specific findings cannot be applied to other populations, this methodological approach can be applied to other occupations, both within the MoD and other workplace environments, where a measure of AFFD based on job-specific hearing critical tasks is required. Collecting information about auditory tasks directly from employees ensures that the results are a true reflection of the occupation in question.

From the current study and the study conducted by Bevis *et al.*^[9] it can be hypothesized that other military cohorts also carry out auditory tasks requiring speech communication, sound localization, and sound detection auditory skills. These professions also use pure tone audiometry as their primary auditory screening method and it is therefore suggested that a similar study is carried out for these cohorts. This would determine which specific auditory skills should be tested as part of their auditory fitness for duty measurements.

Conclusion

This study has produced a list of 17 MCATs carried out by infantry and combat-support personnel in the British Army. Nine of these MCATs are performed by the majority of ranks and roles either weekly or daily and have either major or critical consequence if performed poorly. These nine MCATs should be prioritised for representation by a measure of AFFD for infantry and combat-support personnel to ensure they have the necessary auditory skills for safe and effective deployment on operational duties.

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