

Human factors assessment of armoured fighting vehicle headset function

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ABSTRACT

Crew of armoured fighting vehicles are exposed to hazardous noise levels and are at high risk of noise induced hearing loss. Headsets are compulsory for hearing protection and communication. Noise health risk assessments were undertaken for British armoured fighting vehicles during two training exercises in 2018. As part of this work, a subjective evaluation and assessment of headset function was undertaken to document the condition of two types of in-service headset as perceived by crew, and to identify issues relating to their usability, functionality and comfort. Demographics, functional assessment and subjective evaluation questionnaires were developed using Level 1 of the Human Factors Assessment Framework. Level 1 concerns the initial human factors assessment of a system using paper-based review, visual inspection and/or functional assessment. The functional assessment comprised 12 tasks in three categories: fit, communication and situational awareness. The subjective evaluation comprised 14 questions in six categories: usability, wear comfort, listening comfort, protection, integration and acceptability. Responses were received from 46 personnel. For both headsets, the percentage of crew reporting success for intercom communication tasks ranged from 3% to 29%. Average subjective ratings were negative for wear and listening comfort, with over two thirds of crew reporting headaches and half reporting tinnitus from headset use. Headsets differed in ratings for helmet integration, due in part to non-individualised fit. It is recommended that future headsets are individually-issued and fit-tested in tandem with other protective equipment, and that they are well-maintained and regularly audited to check the level of performance that they are achieving.

KEYWORDS

Headset, hearing protection, human factors, equipment integration, armoured fighting vehicle

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Introduction

Crew of Armoured Fighting Vehicles (AFVs) are exposed to hazardous levels of noise from the vehicle and weapons systems, and are at high risk of noise induced hearing loss. Headsets are compulsory for hearing protection and communication. The attenuation values provided by headset manufacturers are based on measures of ideal headset attenuation achieved using standardised procedures under controlled conditions. Suboptimal fit, use with glasses or eye protection, and general use in a working environment will result in less attenuation than predicted (Health and Safety Executive, 2005).

A subjective evaluation and assessment of headset function was undertaken to document the condition of two types of in-service headset as perceived by crew, and to identify human factor (HF) issues relating to usability and functionality, including fit and integration with other personal protective equipment (PPE) likely to compromise noise attenuation. This headset assessment was undertaken in parallel with noise health risk assessments of British AFVs during two routine Army live fire training exercise periods in 2018.

The objectives of the headset assessment were to:

1. evidence the condition and function of the headsets
2. identify issues affecting fit and use and
3. document adverse effects

The headsets under investigation were the RA180/1025 Crewgard MkII worn with the Crewgard helmet and the RA195/1035 Combat MkII (Figure 1) worn with the UK general issue VIRTUS helmet and subsystems. Both headsets are equipped with a microphone on a boom arm and are designed to attenuate high levels of noise using passive and active noise reduction, with a neckband providing tension to maintain the seals of the circumaural earshells. The headsets differ in their attenuation rating, earshell and support strap design. The Crewgard has a single number attenuation rating (SNR) of 32 dB (INSPEC, 2013a), larger earshells requiring a helmet shape that exposes the ears and an adjustable overhead strap that fits under the Crewgard helmet. The Combat has a lower SNR of 29 dB (INSPEC, 2013b), a lower profile earshell that fits under the VIRTUS helmet and an adjustable head strap that fits over the helmet. The Crewgard helmet, Crewgard headset and Combat headset are not individually issued; however, the Crewgard helmet is available in small, medium and large sizes. The VIRTUS helmet is individually issued and available in four sizes.



Figure 1 Top left: Crewgard headset, Top right: Crewgard headset and helmet, Bottom left: Combat headset, Bottom right: Combat headset with helmet. Images reproduced with permission from Racal Acoustics/Esterline.

Method

Demographics, functional assessment and subjective evaluation questionnaires were developed using Level 1 of the Human Factors Assessment Framework (HFAF) (Humm et al., 2010, Astwood et al., 2014) (see Appendices A, B and C). The HFAF is a technical, three-level framework for gathering HF data and was developed in response to a need for a consistent approach for assessing dismounted close combat systems. The framework was subsequently applied to mounted systems (Saunders Jones et al. 2013).

Level 1 concerns the initial, largely subjective HF assessment of a system using paper-based review, visual inspection and/or functional assessment (Table 1, Figure 2). The three parts of the Level 1 HFAF headset assessment are summarised in Table 2.

Table 1 HFAF level assessment types, from Humm et al. (2010)

Level 1	Level 2	Level 3
Paper-based review, visual inspection and/or rapid functional assessment	Functional performance assessment with simulated or representative tasks	Assessment under highly controlled (laboratory) environment conditions



Figure 2 Simplified representation of the change in reliance on subjective and objective data, from Humm et al. (2010)

Table 2 Level 1 HFAF Headset Assessment demographics, functional assessment and subjective evaluation questionnaire format

	Example questions	Categories	Scoring
Demographics form	Length of service Previously deployed? Head and neck ensemble	N/A	N/A
Functional assessment (12 tasks)	“Were you able to adjust the headset tension?” “Were you able to adjust the level of the intercom?”	Fit Communication Situational awareness	Task Success: yes/partially/no Task Acceptability: acceptable/acceptable with concerns/not acceptable
Subjective evaluation (16 questions)	“How uncomfortable or comfortable was the headset to wear?” “How well or poorly did the headset block out the sound of the vehicle?”	Usability Wear comfort Listening comfort Protection Integration Acceptability	7-point Likert scale (e.g. very poorly, poorly, somewhat poorly, neither poorly nor well, somewhat well, well, very well)

Data collection was undertaken during breaks in live fire training, taking advantage of crews' immediate and relevant experience of headset use. Paper-based review was selected to rapidly identify headset issues that would impact the platform noise health risk assessments, whilst minimising disruption to Army exercises. Note, this approach differs from Level 2 of the HFAF in that headset performance was not assessed during specified, task-based activities under experimenter control.

Individual questionnaires were administered to groups of between three and five AFV crew at a time by the author and a Warrant Officer from the Field Army Environmental Monitoring Team. This allowed group discussion to facilitate the expression and sharing of experiences (Kitzinger, 1995), whilst enabling individuals to give anonymised written responses. Responses were received from 31 Crewgard and 15 Combat headset users.

Results

Demographics

Demographics are presented in Table 3 and split by headset type. It can be seen that the majority of AFV crew report that headsets are not well maintained and that they also wear some form of eye protection when operating the vehicle. Less than half of Crewgard users reported having access to a Crewgard helmet of the correct size, making do with whatever size is available on the vehicle at the time, referred to by one respondent as "*helmet roulette*". This is in contrast to Combat headset users who use their individually issued VIRTUS helmet.

Table 3 Demographics of Crewgard and Combat headset user samples

	Crewgard users (N = 31)	Combat users (N = 15)
Mean service length	6.7 y \pm 8.2 SD	6.4 y \pm 3.5 SD
N previously deployed	39%	100%
N using eye protection/glasses	84%	100%
N with correct size helmet	40%	93%
N with well-maintained headset	29%	47%

Functional Assessment

The functional assessment comprised 12 tasks in three categories (Table 4). Task success and acceptability were scored +1 (yes/acceptable), 0 (partially/acceptable with concerns) and -1 (no/unacceptable). Figure 3 shows average task success and acceptability matrices for Crewgard and Combat headset users, with red, amber and green shading indicating tasks of high, medium and low concern respectively. For both groups, intercom (IC) communication tasks T6 and T7 scored low on success and acceptability. This was supported by comments from the crew including,

"When driving it makes it very hard to hear and understand what the commander is saying"

"Background noise can sometimes be louder than the crew"

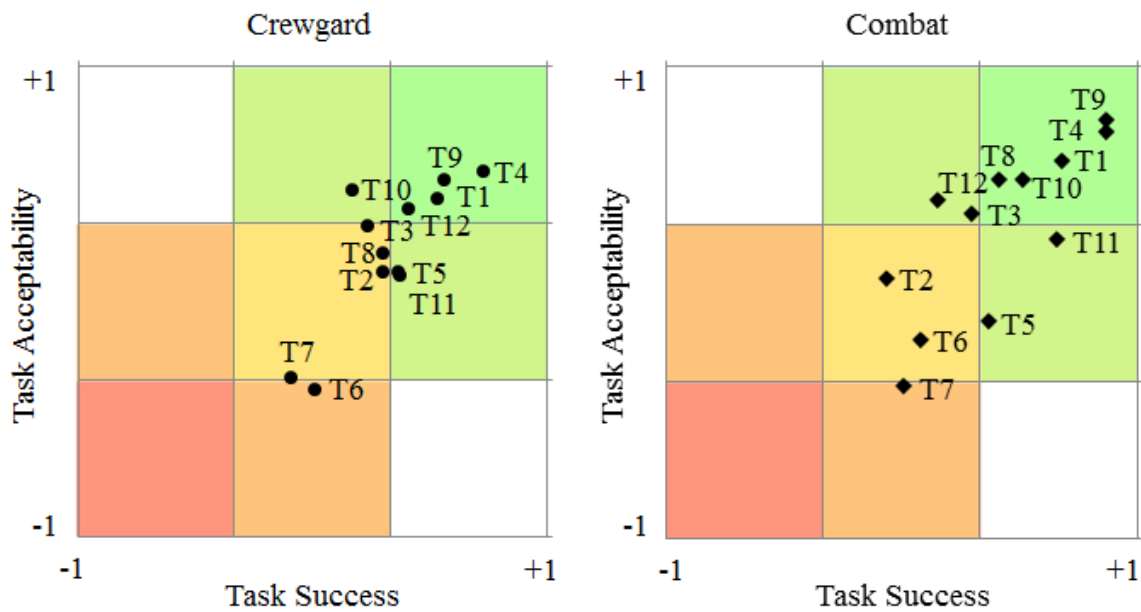


Figure 3 Average task success and acceptability scores for the Crewgard and Combat headsets

Table 4 Tasks, categories and percentage of ‘yes’ responses for task success

Category	Task	Crewgard (%)	Combat (%)
Fit	T1 – Positioning earshells	52	67
	T2 – Adjusting tension	39	36
	T3 – Preventing headset movement	36	36
Communication	T4 – Adjusting level of IC	74	86
	T5 – Hearing own voice over IC	39	36
	T6 – Hearing all crew over IC	7	29
	T7 – Understanding speech over IC	3	20
Situational awareness	T8 – Understanding face-to-face comm.	33	40
	T9 – Hearing vehicle warnings/alarms	55	86
	T10 – Hearing condition of engine	32	57
	T11 – Maintaining SA	40	64
	T12 – Hearing other platforms	56	21

Subjective Evaluation

Responses for each of the subjective evaluation questions scored from -3 to +3. Mean scores for the six categories are shown in Table 5. Overall, the headsets rated negatively for wear and listening comfort, and acceptability.

Table 5 Average response for each subjective evaluation category

Category	Crewgard	Combat
Usability	0.0	0.6
Wear comfort	-1.7	-0.9
Listening comfort	-1.0	-0.5
Protection	0.0	0.1
Integration	-0.3	0.0
Acceptability	-1.5	-0.5

Crew were additionally asked to indicate the location of any specific discomfort or pain from the headset on a diagram and to indicate any symptoms of listening discomfort/noise exposure from a list. Most crew reported experiencing ear pain from headsets crushing their ears. Crewgard users additionally reported pain at the top of the head from the headset overhead strap and buckle under the helmet (Table 6). Comments from respondents included,

“My ears become squashed and I have to keep on taking it off for a few seconds at a time even when I'm driving due to pain.”

“Causes headaches after a while. Hurts outside of ears.”

“Constantly removing headset due to pain”

Table 6 Regions of discomfort or pain from wearing headset

	Crewgard (%)	Combat (%)
Ear pain	90	73
Jaw pain	7	13
Forehead (temples)	13	47
Top of head	45	0
Back of head	16	7

The majority of crew reported experiencing headaches from headset use and half of reported experiencing ringing in the ears (tinnitus) (Table 7). Comments from respondents included,

“after a day of road move ... all of a sudden I get the ringing in the ears, headache and ear pain”

“After about 3 days on any exercise the background noise causes my hearing to suffer to the point where people near enough have to shout to talk to me”

“Ringing in ears due to listening to static”

“Ongoing problem with hearing distortion after exposure to buzzing noises”

Table 7 Symptoms of listening discomfort/noise exposure

	Crewgard (%)	Combat (%)
Ringing in the ears (tinnitus)	47	53
Muffled hearing	23	13
Headache	73	67
Fatigue	30	13
Dizziness	3	7

Average headset and helmet integration scores were negative for the Crewgard headset and helmet combination (-0.4), and positive for the Combat headset and VIRTUS helmet (+0.4). Comments from Crewgard users included,

“The combination of headset and helmet are bad and the headset breaks the seal often”

Average headset and eye protection integration scores were negative for the Crewgard (-0.5) and Combat (-0.3) headsets, with users commenting,

“the arms are pressed into the sides of my head causing some discomfort”

Overall satisfaction was low for both groups, with average scores of -1.7 and -0.7 for the Crewgard and Combat headsets respectively. Comments from respondents included,

“Not robust enough, uncomfortable, not fitted to each individual and Crewgard [helmet]”

Discussion

The objectives of the headset assessment were to evidence the condition and function of the headsets, identify issues affecting fit and use and document adverse effects.

Condition

The majority of crew reported that headsets were not well-maintained. Comments indicate this is a consequence of the use of headsets as a platform mounted system, rather than as PPE:

“Blokes always stand on them or leave them hanging”.

Communication

Communication task success was reported to be low for both types of headset due to *“distorted communications”* and *“a lot of interference and background noise”*. Poor headset signal-to-noise ratio was also cited as the cause for headaches due to *“having to concentrate much harder on what people were saying.”*

Communicating over the intercom in a vehicle is a mission-critical auditory task, in that it is hearing-dependent and failure to perform the task to a specified level will result in decreased safety, efficiency and/or operational effectiveness (Semeraro et al., 2015). During fire and manoeuvre exercises it is mandated that the commander has communication with the driver at all times and that communication is maintained between all vehicles on a firing range and range control. The reported difficulties in communicating over the intercom and the negative impact on performance indicate that this mandated requirement is not being met and highlight the need for improved noise reduction techniques.

Comfort and integration

The majority of crew indicated that headsets were uncomfortable to wear and listen to, with most experiencing headaches and ear pain. The pain from the pressure of the earshells against the pinnae was indicated by some users as 'severe' causing them to remove the headset for momentary relief and compromising their hearing protection.

Achieving a good seal and a comfortable fit are important factors for ensuring users to wear their headset for the entire time that they are exposed to noise, as removing the headset for only a few minutes whilst the vehicle engine is on or during weapon firing severely limits the protection provided (Health and Safety Executive, 2005).

Poor integration with other PPE was source of discomfort, with users of both headsets reporting pain at the sides of their heads from the headset pressing against the arms of their eye protection. Current standard issue eye protection comes in two forms; low impact eyewear with plastic arms and medium impact eyewear with an adjustable, elasticated headband, both available with a prescription option. The latter can be worn with the strap over the headset and helmet to maintain the headset seal. However, crew were observed to use a range of eyewear including personal prescription glasses. Crewguard users alone reported pain at the top of the head from the helmet pressing down on the headset overhead strap and buckle.

Noise exposure

Half of crew reported tinnitus after headset use. Although this symptom of noise overexposure may be perceived temporarily, it is also potentially indicative of auditory nerve degeneration with progressive consequences (Kujawa & Liberman, 2009). Crew reported turning up the intercom level to full in an attempt to improve intelligibility; however, this also increases the level of interference and background noise transmitted through the communication system, resulting in an overall increase in noise exposure. Comments from crew indicate that they attribute the cause of tinnitus to this 'comms noise' as opposed to the passive transmission of vehicle noise through the headset, which again highlights the need for improved noise reduction techniques.

Recommendations & Conclusions

On the basis of these findings it is recommended that future AFV crew headsets are individually-issued, fit-tested, well-maintained and regularly audited to check the level of performance that they are achieving in terms of speech intelligibility and noise attenuation. AFV headsets are currently treated as a platform mounted system; this differentiates headsets from other PPE such as the VIRTUS helmet and subsystems, which are integrated by design. By individually issuing headsets, it is more likely that users will ensure they are properly maintained and stored, and report any defects. Fit, comfort and integration with other PPE are important for ensuring headsets are worn for 100% of the time that users are exposed to noise and that the headset maintains a good seal. Finally, regular checks of speech intelligibility and noise attenuation are essential for safety, efficiency, operational effectiveness and maintaining the hearing health of crew.

The HFAF Level 1 approach has provided a rapid and effective means of collecting HF data from crew during breaks on training exercises, resulting in rich feedback based on immediate real-world experiences. The findings of this assessment are now being used to support requirements generation for future AFV headsets.

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Appendix A - Demographics Questions

Operational Service History

1. Rank
 2. Role
 3. Unit
 4. Length of service
 5. Previously deployed? (Y/N)
 - Roles on deployment
-

Head/Neck Ensemble

6. Helmet
 - Make
 - Condition
 - Size
 - NATO stock number
 7. Headset
 - Make
 - Condition
 - Well maintained? (Y/N)
 - Spare available? (Y/N)
 - NATO stock number
 8. Eye protection/glasses
 - Make
 - Condition
 - Size
 - NATO stock number
 9. Other
 - Make
 - Condition
 - Size
 - NATO stock number
-

Appendix B - Functional Assessment Questions

Fit - wearing helmet, headset, eye protection, neck wear (as appropriate)

1. Were you able to position the headset ear cups over your ears?
 2. Were you able to adjust the headset tension?
 3. Were you able to move your head left and right, and up and down without the headset moving?
-

Communication - wearing helmet, headset, eye protection, neck wear (as appropriate)

4. Were you able to adjust the level of the intercom?
 5. Were you able to hear yourself talking over the intercom whilst the vehicle was moving?
 6. Were you able to hear all crew members talking over the intercom whilst the vehicle was moving?
 7. Were you able to understand what all crew members were saying over the intercom whilst the vehicle was moving?
 8. Were you able to understand crew members shouting to you face-to-face with the vehicle engine on?
-

Situational Awareness - wearing helmet, headset, eye protection, neck wear (as appropriate)

9. Were you able to hear vehicle warning/alarm sounds?
 10. Were you able to hear the condition of the vehicle engine?
 11. Were you able to maintain situational awareness?
 12. Were you able to hear the other platforms move around and fire?
-

Appendix C - Subjective Evaluation Questions

Usability

1. How easy or difficult was the headset to adjust to fit?
 2. How easy or difficult was the intercom to adjust to a suitable level?
 3. How much did the headset hinder or help your ability to communicate with crew members?
 4. How much did the headset hinder or help your ability to maintain situational awareness?
-

Wear Comfort

5. How uncomfortable or comfortable was the headset to wear? If you associate the headset with any specific discomfort or pain indicate its location on the diagram below.
-

Listening Comfort

6. How uncomfortable or comfortable was the headset to listen to? If you experienced any of the symptoms below during or after using the headset, please indicate (ringing in the ears, muffled hearing, headache, fatigue, ear pain, dizziness).
-

Protection

7. How well or poorly did the headset ear cups maintain a good seal when travelling in the vehicle?
 8. How well or poorly did the headset block out the sound of the vehicle?
 9. How well or poorly did the headset block out the sound of the weapons?
-

Integration

10. How well or poorly did the headset fit together with other clothing and equipment when travelling in the vehicle? (Helmet/eye protection/neck wear/other)
-

Acceptability

11. How satisfied are you with the headset?
 12. How confident would you be with using the headset in theatre?
-