Usability of interaction devices whilst wearing personal protective equipment

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ABSTRACT

The impact of wearing personal protective equipment (PPE) on the usability of a set of interaction devices was examined using a single experiment. Participants performed two concurrent tasks: tracking and monitoring/response, while wearing or not wearing PPE, and the resulting performance impact was measured. A differential impact of gloves on device usability according to the glove characteristics was shown. Heavy gloves impaired performance on both response times and the tracking task. Light gloves did not impede task performance. Some headwear was found to hinder colour change detection. Tentative conclusions regarding effects of device orientation and error rates were also made. The results were used to create an update to the extant UK defence standard. Areas proposed for further research include the impact of performance shaping factors on PPE and usability of interaction devices; study of usability impact with different task types; and specific design investigations regarding interaction device design for use with PPE.

KEYWORDS

Human factors, usability, empirical study, interaction device, input device, output device, personal protective equipment

Introduction

Background

There is a paucity of guidance for designers and selectors of systems equipment regarding the impact of wearing personal protective equipment (PPE) on the usability of interaction devices. This study sought to demonstrate an experimental methodology to investigate the effect of PPE on the usability of interaction devices, and to form a basis for future research. Military subject matter experts were involved in prioritising PPE and interaction devices for research, and the output of this research informed updates to the existing UK defence standards. PPE items were selected to be representative of typical workstation activities in a naval operations room.

Handwear and usability

Previous research has shown mixed results regarding the impact of gloves on interaction performance. Batra, et al. (1994) examined manual dexterity across a variety of glove types and found that certain gloves (leather, asbestos, rubber) showed a significant performance difference from bare hands, whilst other lighter gloves (cotton, open finger, surgical) showed no difference. Following an additional test, they concluded that gloves do impact upon manual dexterity, and grip and grasp strength when compared to a bare hand condition, but that differences across glove material are less easy to determine. Taylor and Berman (1982) found a differential impact of gloves on interaction using a number of tasks, varying primarily with fingertip tactility. They also found that differences were greatest in intensive tasks: keying tasks led to greater effects than with a

manual dexterity test battery. Taylor and Berman (1982) also examined the force and travel required before key activation and, though they found no difference between gloved and bare hands, they concluded that a combination of low travel combined with high force is the best compromise to ensure adequate key response with low rates of error. The tasks used for this study were chosen so that they could be generalised to a range of military operator tasks and were also similar to some of those tested by Batra et al. (1994) and Taylor and Berman (1982) – the study reported here used a high intensity task to evaluate the performance deficit induced by a range of military gloves.

Headwear and usability

Goggles, masks and visors have potential to hinder device usability by reducing the visual field, either peripherally or nasally. Tinted lenses may impede colour vision or detection of colour changes – lenses may reduce clarity of sight. Difficulties may also arise in the wearing of contact lenses and glasses. In the down-selection process of PPE for the experimental study, the modalities of vision, audibility and voice were excluded. Therefore, the study focus was on hand tactility and general usability impact when users are wearing widespread general service head protection: snow goggles, desert goggles and an NBC respirator.

Workload

The NASA task load index (TLX) workload questionnaire was administered as part of the study to provide a measure of subjective workload associated with different PPE and interaction devices. This allowed conclusions to be drawn regarding possible ways in which PPE might be exerting an effect on usability.

Aim

The purpose of the study was to assess the effects of PPE on the usability of equipment. Hypothesis: When users are wearing PPE, usability will be significantly lower when compared to the control condition without PPE (measured through objective data in the form of performance scores, and a subjective workload and usability questionnaire).

Method

Approach

A partially balanced incomplete block design was constructed that allowed investigation of the impact of wearing PPE on task performance and workload. Participants were asked to complete tasks at a desk while wearing a set variety of PPE. Their performance and workload were monitored.

The design involved two tasks, eight interaction devices, and nine PPE types. Interaction devices were tested under several task conditions while participants were wearing an item of PPE and while not wearing PPE.

Participants were required to perform two computer-based tasks simultaneously, using the various interaction devices. They were advised that both tasks were of equal importance and that neither should take precedence. The tasks were designed to elicit any differences in usability that may be experienced when wearing and not wearing PPE.

The NASA TLX questionnaire was completed after each interaction device/PPE combination had been tested.

Task 1: Tracking Task

The first task was a 2.5minute manual tracking task. Participants controlled a circular cursor, aiming to keep it as close to the centre of the screen as possible, compensating for unpredictable perturbations introduced by a forcing function. Control of the circle was affected by using up, down, left, and right commands. When using the touchscreen participants pressed these controls on the screen, when using buttons and keys participants pressed the appropriate key and when using either the mouse, tracker-ball, or joystick participants moved the device in the direction needed.

Task 2: Monitoring and Response Task

The computer screens to the left and right of the central screen were used for the reaction task (which ran concurrently with the tracking task). These screens displayed a different colour intermittently. When a colour change occurred participants were required to respond immediately by using a physical 'Respond' button, or, in the case of the touchscreen, they pressed the circle in the middle of the on-screen control box. Performance on this task was assessed based on the mean reaction time recorded to the nearest millisecond, and the number of correct reactions that were made.

Measurements Taken

- Task 1: RMS error: root mean square distance from the cursor controlled by the participant to the target cross-hairs. Thus, perfect performance on the task would yield an average score of zero.
- Task 2: Reaction time (RT, milliseconds) and error rate (taken in two ways: the number of colour changes missed and the number of 'false' responses – occasions on which the button was pressed but there had been no colour change).
- Workload using NASA TLX. This was administered after each interaction device/PPE combination.

Data for all measures were analysed using analysis of variance (ANOVA). The design was an incomplete repeated measures design. Three random effects terms were defined: between-participants (27 degrees of freedom (df)), participant x PPE (243 df) and participant x device (21 df). The design permitted the estimation of the full PPE x device interaction. The primary comparison investigated was the deviation of PPE from control (no PPE) within the different interaction devices.

The independent variables were interaction device (eight levels: button panel, joystick, keyboard, mouse, number pad, touchscreen with finger, touchscreen with stylus, and tracker-ball), and PPE (ten levels: none, snow goggles, combat gloves, NBC gloves, flying gloves, anti-flash gloves, NBC respirator, desert goggles, contact gloves, and arctic mittens).

Participants

The size of the experiment was determined by demanding that a 25% difference in tracking performance should be detectable at a size of 0.05 with a power of 90%. Using the pattern of the partially balanced incomplete block design and previous analysis of a similar tracking task it was concluded that a single replication of the design would meet the requirement, therefore the 28 participants (14 male, 14 female) recruited were sufficient, all of whom were healthy and aged 20-55 years.

Summary of results

1) The interaction devices that resulted in poor tracking task performance (tracker-ball, touchscreen and mouse) also resulted in slowest reaction times to a secondary monitoring task.
2) The PPE that resulted in worst tracking task performance (arctic mittens, NBC gloves, and combat gloves) also resulted in slowest reaction times to the secondary monitoring task.
3) The anti-flash gloves, contact gloves, NBC respirator, desert goggles and snow goggles made no difference to tracking task performance compared to wearing no PPE.
4) The anti-flash gloves, contact gloves, NBC respirator and desert goggles made no difference to response task performance compared to wearing no PPE.
5) When considering tracking task performance and the reaction time to respond to the secondary monitoring task, the effects of PPE and interaction device were independent. Thus, if participants wore PPE that made them worse at the tasks, it made them worse for all interaction devices, not just some. Similarly, if an interaction device made performance worse at the tasks, it did so regardless of which PPE was used.
6) When considering the number of accidental button presses made on the monitoring task, there was remarkably little variation between items of PPE, except for arctic mittens, combat gloves, and NBC gloves. These items of PPE led to nearly six times as many accidental button presses as did other items of PPE, but only when the keyboard and number pad were used as interaction devices.

Conclusion

The aim of the experiment was to investigate the usability of interaction devices whilst wearing PPE with a view to updating guidance for military acquisition of PPE and interaction devices. Results showed that performance deficits to tasks were dependent on the PPE and interaction device in use.

Following this study a short paper recommending updates to design guidelines should be produced.

Impact

This study provides an experimental design suitable for evaluating the interaction between device usability and PPE. The evidence provided by our work has informed future design of human interfaces on military platforms.

References

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