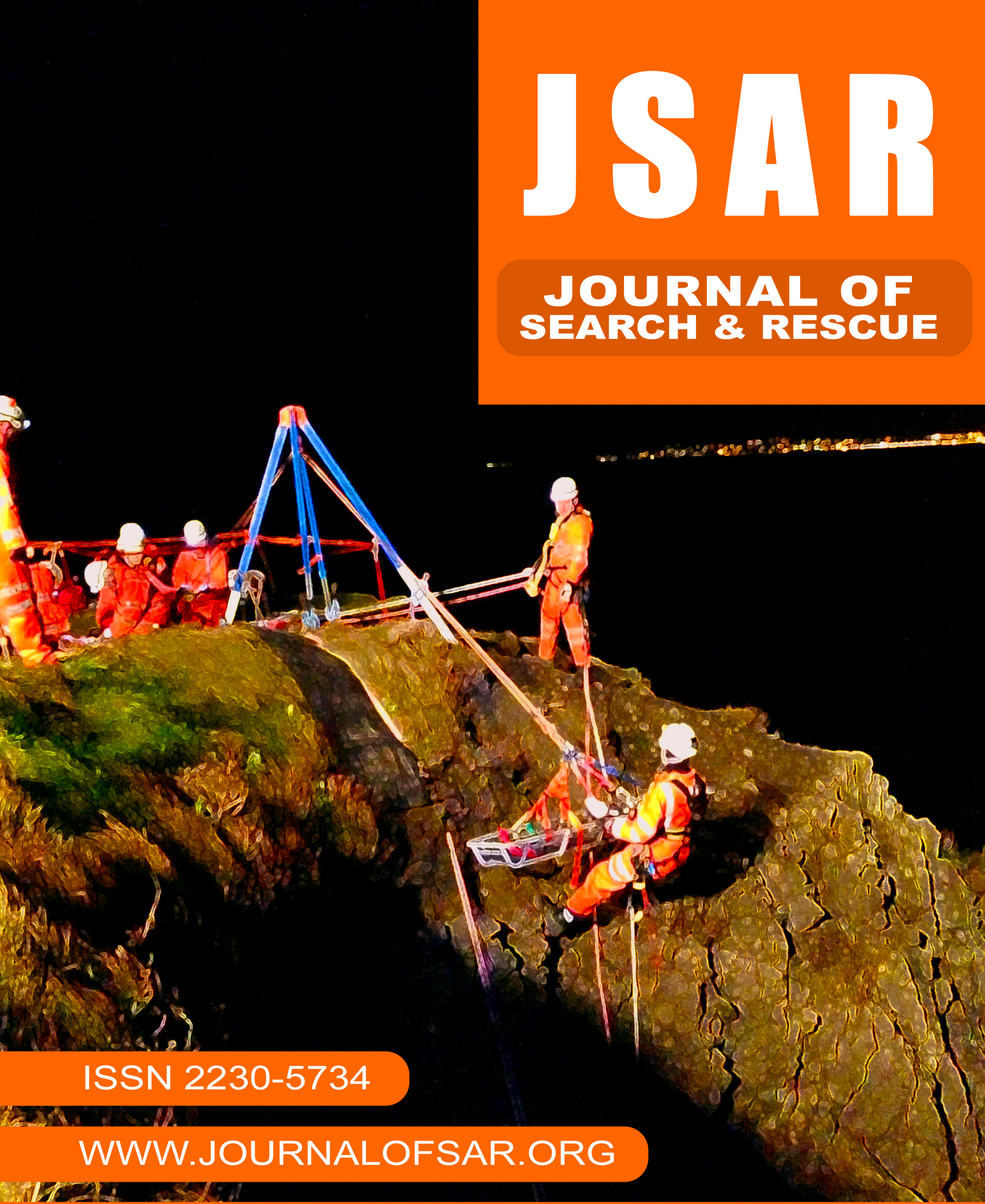
# JSAR

## JOURNAL OF SEARCH & RESCUE



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"A free peer-reviewed electronic journal utilising the internet as a medium for the collation and distribution of original, scholarly, yet practitioner focused material on search and rescue."

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# Foreword

**1 May 2013**

On behalf of the Editorial Board, it is my pleasure to welcome you to our second issue of the *Journal of Search and Rescue* (JSAR). JSAR stands to provide a free peer-reviewed electronic journal utilising the internet as a medium for the collation and distribution of scholarly, yet practitioner focused material on search and rescue.

We still have strong interest from academics and practitioners who want to contribute to the journal, but the process can be time intensive, both in developing an article for submission and the later review process. We still need to spread the word about JSAR and ensure that institutions that have students working on research are encouraged to submit their work in a suitable format for review and inclusion.

It however is encouraging to see across many disciplines a realisation that there is a science to search and rescue and that our practices can be better informed using an evidence based approach. In this issue we welcome recent research from Finland on the use of communications equipment in cold environments – an issue that affects many of us involved in search and rescue.

We look forward to receiving more submissions and from a broader range of SAR disciplines as well.

**Steve Glassey**
**Editor-in-Chief**
**Journal of Search & Rescue**
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# Contents



**Cover Image:**

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**Notice:**

# Case study: perceived usability of emergency communication equipment with and without protective gloves in the cold

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## Abstract

Communication equipment must be usable at accident sites even in an extremely cold environment. The aim was to evaluate the effect of three different glove types on the use of different TETRA phones, and on finger dexterity in the cold (-20 ℃). A VAS and SUS methods were used to evaluate the usability features of the phones. Finger dexterity tests in the cold were carried out to evaluate the effect of gloves on manual performance. Results showed that the type and material of the glove affected the usability features of the phones such as the use of push-buttons and tangent buttons, changing communication group, overall handling, and the compatibility of phone with the glove ($p<0.05$).

**KEYWORDS:** TETRA phone, Gloves, Cold, Dexterity, Usability.

## Introduction

Communication is an essential part of rescue operations. Communication technology, for example, should improve performance and effectiveness in day-to-day rescue service operations (Hainbuchner, 2005). The TETRA digital radio communication system, based on the Terrestrial Trunked Radio standard, is widely used by public safety services and other governmental organizations in Europe, and in many other countries throughout the world. The system provides simultaneous voice and data transfer. Technically, TETRA phones resemble civilian mobile phones, but they must be usable at the site of accidents in all environmental conditions (Hainbuchner, 2005; Valajärvi, 2007). In cold weather conditions, being able to maintain usability and efficiency during a rescue operation becomes a crucial factor.

Manual performance in the cold is affected by cold temperatures, contact with cold surfaces, and the wearing of gloves (Bishu & Kim, 1995; Geng et al., 2006; Havenith et al., 1995). A previous study showed that working bare-handed in extreme cold conditions for more than a few minutes diminishes manual performance (Rogers & Noddin, 1984). Although gloves greatly reduce the risk of hands cooling, they inevitably affect dexterity (Havenith et al., 1995). A protective glove should allow as much dexterity as possible. Factors affecting dexterity relate to the glove material, such as its thickness, elasticity, deformability, as well as to the shape of the glove itself (SFS EN 420+A1, 2010; Tanaka et al., 2010).

Usability can be defined as the extent to which a product can be applied by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (SFS EN 9241-11, 1998). In this context, effectiveness can be defined as the degree of success in dealing with a product. Efficiency refers to the time needed to carry out a task with the product, whereas satisfaction means a positive attitude towards the use of the product (Jokela, 2010). User friendliness (ease of use), technical support and training, i.e. organizational facilitators, are important supporting mechanisms for users' acceptance of a device (Hainbuchner, 2005).

A recently ended project called The Cooperation for Safety in Sparsely Populated Areas (CoSafe, 2011) addressed the issues related to the safety of people living in rural and sparsely populated areas of the Northern periphery countries. The project explored new and improved methods of managing major accidents and disasters in areas with difficult transportation infrastructure, inadequate telecommunications and extreme weather conditions. The project focused on the survival and well-being of disaster victims through effective on-site pre-hospital care, from the scene of an accident to the hospital. This case study was part of the CoSafe project, which aimed to evaluate the effect of three different glove types on the use of different TETRA phones in the cold (-20.0 °C). A further aim was to find the effect of different glove types on finger dexterity in warm (+26.5 °C) and cold (-20.0 °C) conditions.

## Material and methods

The study consisted of two parts: usability tests of the TETRA phones, and finger dexterity tests in both warm and cold conditions.

## Usability tests

*Testers*

Four male rescuers in the Northern Finland volunteered as test users for this study. The number of test users was selected on the basis of previous studies (Virzi, 1992; Nielsen & Landauer, 1993), which have shown that 80% of usability problems are detected by four or five testers. The testers' average work experience was five years and nine months (standard deviation, SD, ± six months). They were all experienced TETRA phone users. Three of the four men were left-handed. The average measure from the top of the middle finger to the end of the palm was 19.3 cm (SD ± 1.5 cm).

*Material*

The testers evaluated three different TETRA phones, P1, P2 and P3 (Figure 1). These phone models are typically used in one Rescue services district in Finland. Their dimensions and weights are shown in Table 1. The average weight of the phones was 279 g (SD 9 g).


*Figure 1. Tested TETRA phones: P1, P2 and P3*

*Table 1. Dimensions and weights of tested TETRA phones*

| Property | P1 | P2 | P3 |
|---|---|---|---|
| Height (mm) | 133 | 147 | 133 |
| Width (mm) | 54 (handle) / 61 (screen area) | 57 | 58 |
| Depth (mm) | 36 | 35 | 31 |
| Perimeter (mm) | 180 (handle) /194 (screen area) | 184 | 178 |
| Weight (g) | 288 | 270 | 278 |

The usability tests were performed using three different glove types: firefighters' leather gloves, firefighters' leather/textile gloves, and work gloves (Figure 2 A–C, Table 2), as well as bare hands, during a simulated communication situation. The work gloves were of various different styles of leather gloves with lining. The size of the gloves was selected on the basis of the size of the users' hands.

A) B) C)

*Figure 2. Firefighters' leather gloves (A), firefighters' leather/textile gloves (B), and work gloves (C)*

*Table 2. Materials used in different gloves*

| Glove | Material | Thickness (mm) |
|---|---|---|
| Leather glove | Outermost material: Leather (calf, reindeer), knuckle protection<br>Inner lining: Nomex<br>Cuff: split leather<br>Moisture barrier: Porelle membrane | 3.5 (glove)<br>1.4 (leather) |
| Leather/textile glove | Inside, back of hand: special nappa calfskin<br>Finger joint, knuckle protection, palm area and thumb interior: PBI gold elastic knitted fabric<br>Inner lining: close-meshed knitted, 100% Kevlar<br>Cuff: cracked calf leather<br>Moisture barrier: Porelle membrane<br>Reflective strip (25 mm) on cuffs | 4.5 (glove)<br>2.1 (leather) |
| Work glove | Outer material, hand and cuff: Leather or textile<br>Fabric lining | variation between 3.5 - 4.3 |

*Test procedure*

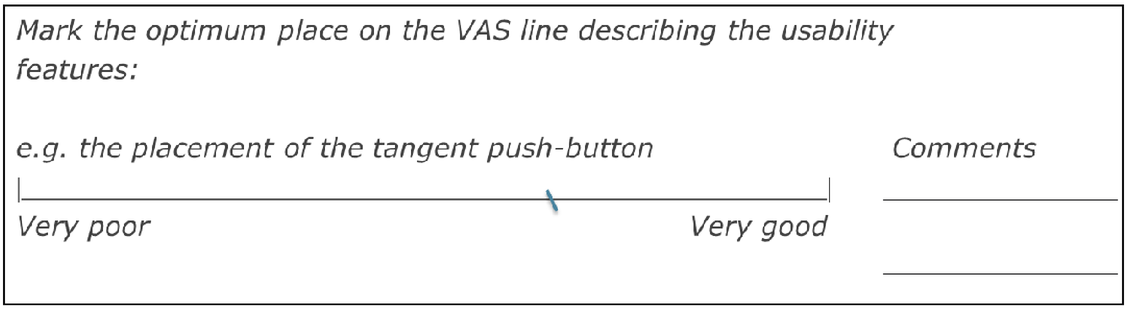
The usability tests were performed as simulated communication situations. Each tester performed the simulation with three different phones using three different glove types as well as bare handed. The situations were set in random order. The testers were allowed to use the TETRA phones beforehand, in order to become familiarized with them. Before the tests, the phones were placed in the chamber to cool. The simulated communication situation was controlled, and instructions were given by phone. The tests were performed in two separate climatic chambers at −20.0 ºC (± 0.3 °C) and at a wind speed of 0.3 m/s. The controller of the simulation was outside the chambers to avoid audibility from the same room. The simulation included the following tasks: responding to a call, conversing by phone, changing the communication group two different ways, and adjusting the volume. The testers indicated when the task was completed. The time used for each task was not recorded systematically, as the length of the conversations during the simulation varied. The simulation lasted between five and eight minutes.

The testers stayed inside the chamber during the tests, their physical workload being very light, about 75 W/m$^2$ (ISO 8996, 2004). They were wearing firefighters' protective gear with a long sleeved shirt and long-legged thin trousers and their own underwear. The thermal insulation of the protective gear was about 3 clo (0.47 m$^2$K/W) (Jussila & Anttonen, 2011).

*Measurements*

Visual Analogue Scale (VAS)

After the simulated communication tasks, modified visual analogue scales (VAS) were used to determine the usability features of the three different phone types (Price et al., 1983; Beauchamp, 1999; Nevala & Tamminen-Peter, 2004; Lintula & Nevala, 2006; Toivonen et al., 2011). The VAS is a 100 mm long continuous line with endpoints anchored by 0 (very poor) and 100 (very good). The VAS score is a measured distance (expressed in millimeters) from the 0 scale point. The participants were asked to mark on the line the point that indicated their evaluation of the following features: fit for hand, the shape and weight of the phone, the placement of the tangent push-button, the shape of the push-buttons, the clarity and size of the screen, screen update in the cold, changing communication group, audibility of the speaking voice, volume control and compatibility of phone with gloves. An example of the VAS questionnaire is presented in Figure 3. In addition, an overall evaluation of the phones and overall functionality were carried out. The questions were prepared in co-operation with experienced rescue service professionals.


Mark the optimum place on the VAS line describing the usability features:

e.g. the placement of the tangent push-button

Comments

Very poor

Very good

*Figure 3. An example how the participants marked (\) on the 100 mm long continuous line the point that indicated their evaluation of the usability feature*

System Usability Scale (SUS)

The global view of system usability with respect to the TETRA phones was evaluated using the System Usability Scale (SUS). The statements covered the following aspects of system usability: training, complexity, and need for support. System usability was presented as the theoretical percentage of 'perfection' on a scale of 0 to 100. The SUS questionnaire is regarded as a valid tool for usability assessment (Brooke, 1996).

Order of Superiority and Free Comments

The testers were also asked which TETRA phone they would rate the best, second best, and third best in the case of a disaster (Lintula & Nevala, 2006). All of the free comments regarding the usability of the phones were taken into consideration. The tests were videotaped.

*Statistical analysis*

The data are presented as mean values and standard deviation (SD). The Shapiro-Wilk test was used to test the normality for the data. For normally distributed variables, the parametric One-way analysis of variance (ANOVA) was used, followed by Bonferroni post hoc tests to test the equality of the mean values of the VAS scores between each situation. For non-normally distributed variables, the Kruskall-Wallis, followed by the Mann-Whitney post hoc test was used. The differences were considered statistically significant if $p<0.05$. The SPSS software (version 18) was used for statistical analyses.

## Finger dexterity tests

*Material*

The glove types were the same as those used in the usability tests (Table 2). Three right hand gloves of each type were tested. The gloves were somewhat already used, i.e. not new. They were conditioned for 20 hours before measurements in test conditions.

*Test procedure*

The finger dexterity tests with different gloves were performed according to the standard SFS EN 420 + A1 (2010) with minor modifications: tests were conducted in both warm (+26.5 ℃) and cold (-20.0 ℃) conditions by one experienced tester according to the standard.

The tests were performed with five centerless ground stainless steel test pins. The tester picked up a pin by its circumference between his gloved forefinger and thumb without any other means of assistance (Figure 4). The same pin had to be picked up three times within 30 seconds without undue fumbling. The pins were 40 mm long and 5 mm, 6.5 mm, 8 mm, 9.5 mm and 11 mm in diameter. They were not conditioned before testing. The tester was kept in thermal balance during the tests by sufficient clothing and by breaks between tests in warm conditions. The result value, i.e. level of performance (Table 3) corresponds to the smallest diameter of pin that was picked up according to the test procedure. The results are given as means (± SD) of each different glove type (n=3 per glove types).

*Figure 4. Finger dexterity tests with different gloves using five test pins*

*Table 3. Levels of performance in finger dexterity test (SFS EN 420 + A1, 2010)*

| Level of performance | Smallest diameter of pin fulfilling test conditions (mm) |
|---|---|
| 1 | 11 |
| 2 | 9.5 |
| 3 | 8 |
| 4 | 6.5 |
| 5 | 5 |

# Results

## Usability tests

As there were no statistically significant differences in the functional features of the phones when used bare handed, the results were presented as mean values of all phones (pooled data), as well as separately (Figure 5A-D). The pooled data showed that the different glove types affected the usability assessments of the phones (Figure 5A).

The data from each phone separately (Figure 5B-D) showed that, in general, the usability of the push-buttons of the phones differed significantly depending on whether they were used with different gloves or bare handed. For each feature, the usability of the phones was evaluated as best when the firefighters' leather gloves were used compared to situation when the other gloves were worn. The poorest usability values resulted from the use of the leather/textile glove. The usability of the tangent push-button when P1 and P3 were used with gloves differed significantly from that when they were used bare handed. Correspondingly, significant differences in changing communication group were found when P2 and P3 were used. P3 differed significantly in all usability features depending on whether it was used with either different gloves or bare handed, with the exception of fit for hand.

It is noteworthy that the use of volume control of P1 was better with all tested glove types than bare handed (Figure 5B). The volume control of P1 was in the form of a roller, whereas the volume control of P2 and P3 was by push-buttons.

The SUS scores for P1, P2 and P3 were 51, 81, and 77, respectively. As regards communication in extreme cold conditions, three out of the four testers chose P2 as the best communication device in the case of a disaster, while one tester preferred P3.

P1 was considered the least suitable for communication in disasters in the cold by 50% of the testers. The free comments revealed that cold stiffened the push-buttons and tangent buttons, making the operation more difficult.

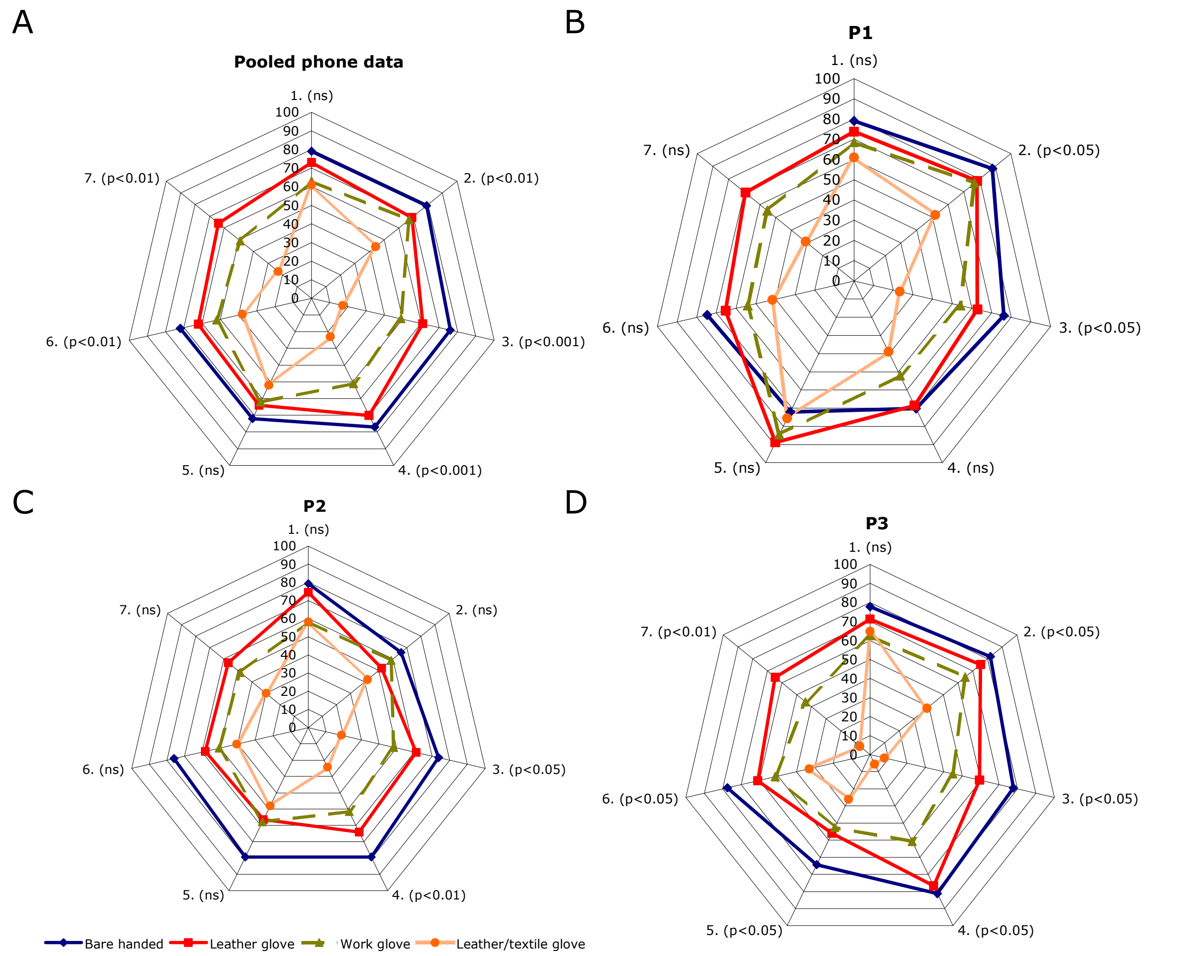



*Figure 5. Mean values of perceived usability (visual analogue scale, from 0 = "very poor" to 100 = "very good") of TETRA phones with different gloves as rated by rescuers (n=4) after simulated tasks. Significant difference, p<0.05, ns = not significant. Numbers in figure: 1 = Fit for hand, 2 = Use of tangent push-button, 3 = Use of push-buttons, 4 = Changing communication group, 5 = Volume control, 6 = Overall handling, 7 = Compatibility of phone with gloves.*

## Finger dexterity tests

Table 4 presents the mean level of finger performance (± SD) according to the finger dexterity tests with different glove types in warm (+26.5 ℃) and cold (-20.0 ℃) climates.

The best level of finger performance both in cold and warm conditions was maintained with the firefighters' leather glove. The glove consisting of both leather and textile decreased the level of performance most at both temperatures. The cold decreased the average level of finger performance by about 0.7 - 1.0 compared to warm conditions.

*Table 4. Results of finger dexterity tests, n=3 per glove types*

| Glove | Level of performance (mean ± SD) at +26.5 °C | Level of performance (mean ± SD) at -20.0 °C |
|---|---|---|
| Leather glove | 3.3 ± 1.0 | 2.3 ± 1.3 |
| Work glove | 2.7 ± 1.4 | 2.0 ± 1.8 |
| Leather/textile glove | 1.2 ± 1.1 | 0.4 ± 0.9 |

# Discussion

This case study focused on the use of communication equipment in rescue operations in cold conditions. In these cases it is important to simultaneously guarantee the usability of phones and to maintain the finger dexterity of the firefighter or first responder. The best possible match between the product and its users can be achieved by evaluating the product within an authentic or simulated operating situation with real users (Pheasant, 1996). In our study, the phones were tested in simulated operations. The study was planned together with researchers and experienced rescue service professionals, enabling us to identify the work tasks that required the use of a TETRA phone and to choose proper testing methods. The time used for each task was not recorded systematically, as the length of the conversations during the simulation varied. Four experienced males volunteered as test users for the usability tests. The number of test users was selected on the basis of previous studies (Virzi, 1992; Nielsen & Landauer, 1993; Spielholz et al., 2001). The small number of testers means that the results of this case study cannot be scientifically generalized. However, the results do demonstrate the tendency of practical results in extreme cold conditions in sparsely populated areas.

The use of gloves affects manual performance (Bishu & Kim, 1995; Havenith et al., 1995). The present results support previous studies by showing better usability of phones when used bare handed than with gloves. The lowest temperature in which it is possible to maintain practical bare-handed performance for more than a few minutes is −18 °C (Rogers & Noddin, 1984), a person should be able to use a communication device in extreme cold conditions while wearing protective gloves. The firefighters' leather gloves were perceived as the most suitable for use with the TETRA phones. The leather gloves also provided better dexterity than the other gloves in both warm and cold temperatures. The overall thickness of the leather gloves (including leather and lining) was less than that of the other gloves. The thickness of the glove has a strong negative correlation with finger dexterity (Havenith & Vrijkotte, 1993).

The test gloves were somewhat already used, and we assumed that a dirty glove stiffens more in the cold than a clean glove. The work gloves were of various styles, which caused high standard deviation in the dexterity results. Furthermore, information regarding the bending stiffness of the glove materials in the cold would give more detailed, precise knowledge of the effect of gloves on finger dexterity and on the usability of communication devices when wearing the gloves. If the duration of the tests had been longer or if the testers had been cooled before the test, the effect of cold on their finger dexterity would have been even more significant.

As regards the SUS scores and order of superiority of the phones, P2 was chosen as the best communication device in the case of a disaster in the cold, while P1 was considered as the least suitable. However, P1 had the highest average VAS values in fit for hand, use of push-buttons, tangent and volume control, and overall evaluation. The compatibility of the phone with the gloves was highest when P1 was used with each glove type. P1 was also rated the best with different glove types in the overall handling of the phone and the use of the push-buttons. The volume control of P1 was in the form of a roller, and was thus evaluated as being easier to use with gloves than P2 and P3, in which volume was controlled by push-buttons.

However, the compared TETRA phones varied only slightly in size and weight. P1 was barely heavier and had more depth and a longer perimeter than the other phones. In addition, the phones somewhat differed in shape and in the placement and depth of the push-buttons, and these variations presumably led to the differences in usability when gloves were worn. A recent study (Herring et al., 2011) demonstrated that as the handle perimeter of the hand-held tool decreased, the handle became less preferred when using layered gloves.

The SUS system is an effective and reliable tool for measuring the usability of a wide variety of products. Bangor et al. (2009) compared the SUS and a seven-point adjective-anchored Likert scale (N = 964), and found that the Likert scale scores correlate well with the SUS scores (r = 0.822). Thus in the present study, P2 (SUS score 81) and P3 (SUS score 77) were rated acceptable for system usability; P1 was in the margin of not acceptable (SUS score 51).

The VAS method has been used in several studies (Price et al., 1983; Jensen et al., 1986; Nevala & Tamminen-Peter, 2004; Lintula & Nevala, 2006). The ratings were originally used as outcome variables when back symptoms were analyzed in geriatric care. In recent studies, however, the method has been modified to evaluate various topics of interest (Lintula & Nevala, 2006). Although a questionnaire to evaluate the usability of mobile phones exists – the Mobile Phone Usability Questionnaire (MPUQ) (Ryu & Smith-Jackson, 2006) – it consists of six parts and 72 questions, and we considered it too wide for our study.

The study provides information for device development, by finding the most significant factors of the TETRA phones when they are used in the cold. However, detailed information on the use of the communication devices in long-term cold exposure is still needed. Factors such as finger mobility and material elasticity should be taken into account in the development and design processes of protective gloves for firefighters and first responders.

## Conclusions

Communication is an essential part of rescue operations work. In cold conditions it is important to simultaneously guarantee the usability of the phone and the manual and finger performance of the rescue worker. This study aimed to evaluate the effect of different glove types on the use of Tetra phones and dexterity in cold conditions.

The perceived usability features of the tested TETRA phones did not differ significantly when they were used bare handed. The phones only slightly differed in size, shape, and the placement and depth of push-buttons. Volume control in the form of a roller was evaluated as being easier to use than push-buttons. However, the most significant differences in usability features were found when the different gloves were worn during the use of the phones. These differences were in the use of push-buttons and the tangent, in changing communication group, in overall handling, and in compatibility of the phone with the gloves. The firefighters' leather gloves were perceived as the most suitable for use with TETRA phones. They provided better dexterity than the other gloves in warm and cold temperatures.

The results of this study provide information on the properties of communication devices and protective gloves that will help to support the optimum selection of communication equipment and protective gloves for rescue services in cold weather areas.

## Acknowledgements

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