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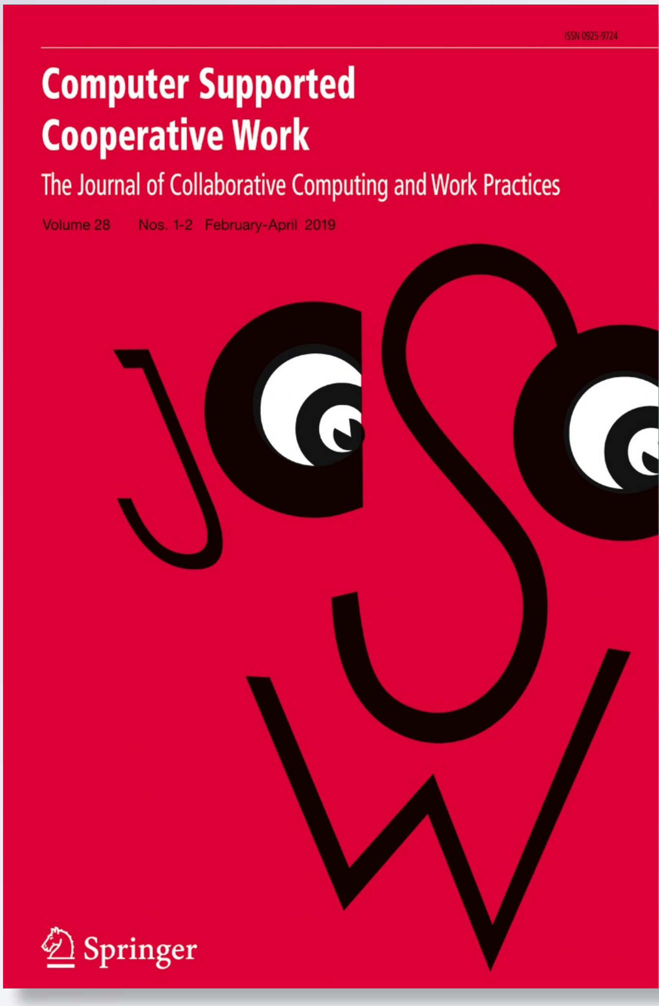

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RescueGlass: Collaborative Applications involving Head-Mounted Displays for Red Cross Rescue Dog Units

Christian Reuter[1]*, Thomas Ludwig[2] & Patrick Mischur[3]
*[1]*Science and Technology for Peace and Security (PEASEC), Technische Universität Darmstadt, Karolinenplatz 5, 64289 Darmstadt , Germany ();* [2]*Cyber-Physical Systems (CPS), University of Siegen, Siegen , Germany;* [3]*Institute for Information Systems, University of Siegen, Siegen , Germany*

Abstract. On-site work of emergency service teams consists of highly cooperative tasks. Especially during distributed search and rescue tasks there is a constant mix of routinized and non-routinized activities. Within this paper we focus on the work practices of the German Red Cross Rescue Dog Units who deal with several uncertainties regarding the involved dogs, the fragility of the respective situations as well as issues of using technologies under enormous time pressure. Smart glasses provide possibilities for enhanced and hands-free interaction in various contexts and a number of approaches have already been applied, aiming at efficient use of the respective technological innovation in private and professional contexts. However, the collaborative potential of smart glasses in time-critical and uncertain situations is still unexplored. Our design case study examines how the on-site work of emergency service teams can be supported by smart glasses: Based on examining the work practices of the German Red Cross Rescue Dogs, we introduce 'RescueGlass' as a coordinative concept, encompassing hands-free head-mounted display (HMD) application as well as a corresponding smartphone application. Finally, we describe the evaluation of its use in the field of emergency response and management. We show how current features such as 'fog of war' or various sensors support the cooperative practices of dog handlers, and outline current technical limitations offering future research questions. Our paper provides an initial design probe using smart glasses to engage in the field of collaborative professional mobile tasks.

Keywords: Head-mounted displays, Smartphone, Rescue dog units, Emergency management, Collaboration, Empirical study, Prototype, Evaluation

1. Introduction

Many studies within the field of Human Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW) have already demonstrated that emergency response is a highly cooperative setting in which the work of individuals and their agencies is often closely interwoven (e.g. Heath and Luff 1992; Ludwig et al. 2015; Pipek et al. 2014; Reuter et al. 2014). Several studies have shown potential of innovative IT solutions in these situations (e.g. Ley et al. 2014; Liu 2014; Schafer et al. 2007). Broadly, it is typically the case that many different actors – even within the same organization – have to synchronize their activities, and it is no exaggeration to say that effective coordination can be a matter of life or death. The rise of (asynchronous) mobile technologies and Web 2.0 capability have enabled new methods for supporting work settings within spatially distributed emergency response, e.g. communication between control rooms and units on-site (Heard et al. 2014; Ludwig et al. 2013; Reuter et al. 2014). However, current approaches which aim to support the work of emergency services with mobile technologies are often compromised by (1) the need for information to be ready to hand in rapidly changing, real-time environments, and (2) the effect that end users can suffer from a flood of information of varying quality.

By providing head mounted displays (HMDs) that allow hands-free interaction, modern wearable technologies (e.g. smart glasses) have provided a possible means for some of these challenges to be faced. Still, so far, very little empirical evidence exists demonstrating that these devices might add value to the work, or that they can be easily integrated into existing practices, especially during emergencies (Fuentes Fernández et al. 2014; Lukosch et al. 2015b). Therefore, we aim to address the question how and whether the use of wearable technology – in this case, smart glasses – can support the highly collaborative and mobile on-site work of the emergency services. Our design case study aims to explore the potential uses of new technologies within the field of emergency management, in particular the possible usage of free-handed smart glasses. We do this through a specific exploration, mindful of the fact that emergency situations, in their nature, include many unknowns, such as people and organizations involved, location, time and length, available infrastructures, weather conditions. The study identifies the mobile on-site practices of the Rescue Dog Units of the German Red Cross organization and concerns itself with the following the research question: *What are the potential benefits and challenges of supporting mobile on-site Rescue Dog Units with hands-free and HMD concepts?* The study serves as an exploration of the way in which wearable technology can supplement other resources in a time-critical context.

In the following, we analyze related approaches (section 2) and then we present our general research approach (section 3). In a qualitative empirical study, we then explore the potential for using smart glasses in the context described (section 4). Based on our pre-study findings, we derive requirements for an approach to cooperative distributed search and rescue tasks and we implement the mobile application 'RescueGlass' based on an Android application and Google Glass visualization (section 5). Afterwards, we present the results of our evaluation (section 6), the results of a comparative study (section 7) and finally we discuss those results (section 8).

2. Related work

Understanding and supporting the cooperation structures of emergency services become a central concern in the research field of CSCW and HCI. It is particularly interesting as it stands at the juncture of various distributed work practices found within on-site units and in cooperation with and within the control rooms which coordinate them. In the following, we review the related work in both areas regarding concepts of HMD and identify a research gap in the current state-of-the-art.

2.1. HMDs and smart glasses

It was the miniaturization of computer hardware (Weiser 1999) that made wearable computing possible. It is defined as the 'study or practice of inventing, designing, building, or using miniature body-borne computational and sensory devices. Wearable computers may be worn under, over, or in clothing, or may also be themselves clothes' (Mann 2014). Wearables – the technology of wearable computing – can take different forms including smart watches and smart glasses. The latter seems to be particularly appropriate for displaying information to the user on a hands-free basis. Display devices worn as helmets or as smart glasses are often referred to as HMDs (Dörner et al. 2013). Their miniature displays, which are optically transparent, are placed in the wearer's field of view and therefore constitute a form of virtual or augmented reality, depending on the degree of transparency. Displays which possess no transparency are called virtual reality displays and if they have a 'see through' quality (normally obtained by adding cameras) they are termed 'augmented reality' (Tönnis 2010).

AR is a concept designed to enrich reality by the help of artificial and virtual elements. Artificial objects create views which allow the seamless blending of real and virtual elements. Azuma (1997) attributes three characteristics to AR: (1) it combines real and virtual information; (2) it is interactive in real time, and (3) it acts in a three-dimensional environment. It is important that these objects are continuously adjusted, taking account of and adjusting to the user's current position and viewing angle (Dörner et al. 2013). AR enables users to see the real world and let them experience virtual objects, layered over the real world (or otherwise connected with it), at the same time. This layering does not replace the real world with virtual information but rather enhances it (Kipper and Rampolla 2012). Several different forms of displays are currently available including e.g. space- and environment-fixed displays, movable displays (Window-into-the-World) and even handheld displays (Tönnis 2010).

The idea of developing smart glasses was born of the desire to build an automatic welding helmet, which would not only darken and lighten automatically, but also enhance the environment with other information. This principle was called 'augmediating' (Mann 2012a). In the first generation, a camera and a display were the main components. Further development included the integration of eye tracking with a camera and display (2nd generation). The principles behind it involve light beams captured by the eye and simultaneously forwarded through a beam conductor to the camera-system. Later generations of smart glasses addressed problems with the adjustment of the focal points (3rd and 4th generations). The use of a focal point control mechanism made it possible to match the focal point of the glasses with that of the eye, which enabled long-time wearing of the glasses without eye strain (Mann 2012a).

A radically new type of communication was promised by the smart glasses of today such as Google Glass (see Figure 1 below) as they displayed all the necessary functions of a connected mobile device directly into the user's field of view (Klinke and Stamm 2013). An HMD in the form of a prism is placed above the right eye and projects the picture into the user's field of view. The picture itself is produced in the attached display and is then transferred. The user sees the picture as semi-transparent so that the "real" view is still partially visible. To be able to use the glasses, a mobile device is necessary which provides all-important content. Resulting applications, e.g. for laboratories, provide 'situated access to information (e.g. protocols, instructions) and […] document lab work in-process through hands-free interaction' (Hu et al. 2015). As Starner (2013) mentioned, the idea behind Google Glass was to 'reduce the time between intention and action'. On a mobile device, fast interaction can make all the difference between a successful interface being used and an ineffectual device that remains in one's pocket. The delay between intention and execution is connected to the number of practical applications of the respective system. There is ample evidence which shows that delays and interruptions to information provision result in less daily use and sometimes the total rejection of the device (Starner 2013). Nonetheless, there has been considerable interest in implementation and evaluation of Google Glass in a variety of contexts, including medical settings (e.g. Muensterer et al. 2014), activity recognition (e.g. Ishimaru et al. 2014), as an assistive technology (see e.g. McNaney et al. 2014) in support of the so-called 'flipped' classroom (see Parslow 2014) and for the assessment of the visitor experience in art galleries (see Leue et al. 2015).

In their special issue on collaboration in AR settings, Lukosch et al. (2015a) outline various approaches not just for individual users but also for face-to-face collaboration and remote collaboration. In particular, the goal of AR in remote collaboration is often to remove spatial barriers by adding interaction elements and cues, whereas face-to-face collaboration via AR further enhances these cues. A study revealed that HMDs enable 'more frequent directing commands and more proactive assistance' compared to handhelds (Johnson et al. 2015). The capability for collaboration and especially joint use of AR has also been shown (Schnier et al. 2011). Systems dating back to the 90s have focused on games and collaborative learning, but also navigation, inter-organizational information exchange, and security-related

Figure 1. Google Glass – an HMD ("Google Glass with frame" Mikepanhu, CC BY-SA 3.0).

domains (Lukosch et al. 2015a). One interesting application field for collaborative use is the field of emergency management.

2.2. HMDs within emergency management

Carenzo et al. (2014) state that 'despite some limitations (battery life and privacy concerns), Glass is a promising technology both for telemedicine applications and augmented-reality disaster response support'. Enhanced speed between intention and interaction seems to have significant benefits for the domain of emergency management. It is reasonable to suppose that in almost all cases, updating information rapidly and accurately is immensely valuable. However, the uncertain character of emergencies means that the rapid provision of information for all organizations involved is a non-trivial problem (Turoff et al. 2009). In this field, decisions have to be made constantly and appropriate actions have to be undertaken 'under conditions of incomplete or inaccurate information in a context of changing and possibly ambiguous hazard consequences and response objectives […] under considerable time pressure' (Paton 2003). Kwon et al. (2011) identified five important factors for the effectiveness of the collaboration of public safety organizations: information sharedness, operational awareness, communication readiness, adaptiveness, and coupling. They emphasize that these factors should be taken into consideration when designing new public safety communication systems, e.g. HMDs.

Almost two decades ago, Azuma (1997) mentioned areas which at the time were in need of a breakthrough, such as HMDs for outdoor use. He described futuristic navigation applications for people walking outdoors, such as soldiers advancing upon their objective: 'today [1997] these individuals must pull out a physical map and associate what they see in the real environment around them with the markings on the 2D map'. We are now beginning to see some of these challenges addressed. Although there is substantial literature concerning the use of HMDs (see above) and research into emergency management is now commonplace (Convertino et al. 2011; Grabowski and Roberts 2011; Semaan and Mark 2011), there is relatively little literature which combines the two. Although there are manifold approaches regarding the use of HMDs in various application areas such as the indoor-localization of objects (Funk et al. 2014) or AR-based geocaching (Tursi et al. 2014), there are only very few approaches concerning the usage of such concepts and technologies for the coordination and navigation of emergency services.

Nilsson et al. (2011) present an HMD application for coordinating activities between co-located units from different emergency services in a command-and-control room (Figure 2a). The application was created to enable several individual views of a map at the same time, a process necessitated by the separate services using their own distinct terms, symbols, and structures. Nilsson et al. showed that an information exchange between diverse actors is simplified by using HMDs, even in the absence of direct eye contact. The required data for real-time communication was gathered and forwarded in-situ by the emergency units but it should be noted that this application focuses on the support of teams concentrating on a map in the control room and not on the on-site support of distributed mobile units.

Based on Google Glass, Fuentes Fernández et al. (2014) developed an application for the Red Cross to triage accident victims (Figure 2b). Arriving at an incident, medical teams have to classify and categorize the injured person without delay, based on their state of health (triage). This process often relies on incomplete information and has to be carried out under dangerous conditions and emotional pressure, often with limited resources. The aim of the application is to use speech-based commands to manage the available data, and to assign the patients according to the known configurations of ambulance vehicles and hospitals. The application also allows additional information to be displayed to assist the triage process, but it neither includes navigation functionality nor supports collaboration nor awareness among actors.

Lukosch et al. (2015b) aim to improve the situational awareness of policemen with a collaborative AR system which allows the remote annotation of a local scene (Figure 2c). Evaluations have shown that remote guidance improves situational awareness. While the application shows the cooperation of on-site operators and the control center, it does not show collaboration among on-site units. A similar system has been developed by Datcu et al. (2014), supporting communication and situational awareness between policemen and security inspectors in investigation and preparation of safe locations for winess protection. Likewise, Poelman et al. (2012) introduce and evaluate an AR system that allows remote experts to collaborate with local investigators on a crime scene investigation to secure evidence.

In their survey on AR, van van Krevelen and Poelman (2010) mentioned the potentials for the use of AR technology for 'navigational support, communication enhancement, repair and maintenance and emergency medicine'. Addressing one such field, Sánchez et al. (2016) explore the possibilities of Google Glass technology for participatory multi-agent indoor evacuation simulations, and suggest combining devices with indoor tracking services, e.g. personalized evacuation routes in real time.

Wilson and Wright (2009) investigated the use of a custom HMD integrated into a facemask for firefighters in scenarios where buildings with low visibility have to be navigated. This HMD technology was monocular with a color 640 × 480 pixel LCD display which neither integrated the real world nor the additional information into the

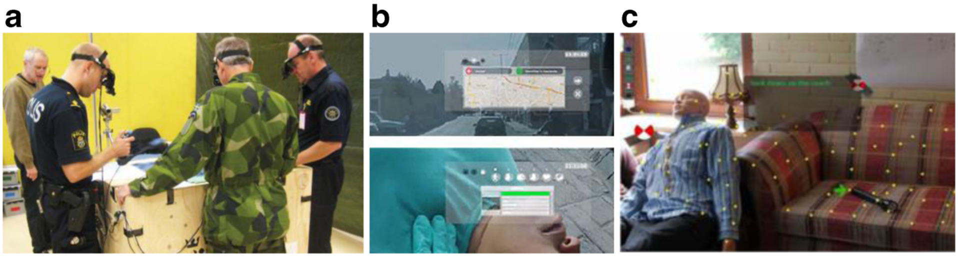

Figure 2. Examples of smart glass in emergencies (left (**a**): Nilsson et al. (2011), middle (**b**): Fuentes Fernández et al. (2014), right (**c**): Lukosch et al. (2015b)).

sight. Although not focusing on emergency management, Tursi et al. (2014) presented AiRCacher, a mobile app for virtual geocaching enhanced with AR. They showed that people became social sensors, able to provide geo-located social data which makes it possible to supply systems with the necessary data (Ludwig et al. 2013). The information gathered this way allows immediate visualization with the help of the AR environment and the information can be used for subsequent analysis.

Moreover, Wu et al. (2013) researched HMDs and multi-surface displays to support emergency medical teams with an interactive checklist. The aim of the HMD was to reduce attentional shifts. Unfortunately, no further details about the application are available, nor is there any evaluation material on hand. In addition to this, various studies on usage during surgery are accessible, one of them being Mentler et al. (2016), who discuss the usability and acceptance of smart glasses for photo-enriched documentation during surgery. Rolland et al. (2005) introduced miniature projectors on an HMD allowing face-to-face communication and visualization of shared 3D virtual objects to be used for medical visualization.

As the case studies mentioned above have shown, the value and usefulness of data visualization depend on the specific form of visualization chosen. Funk et al. (2014) show that users found the availability of an overview of the entire situation to be simplest and most effective. It also seems that, in addition to the use of an overview map, pictures and videos can be helpful resources (Mentler et al. 2016). It is also conceivable, however, that problems might arise during the operation. Nilsson et al. (2011) point out that it is important to avoid misunderstandings while displaying the relevant pieces of information. This requires the individual actors to have access to various views on the application. In addition, Fuentes Fernández et al. (2014) argue that a speech-based HMD interface, such as that of Google Glass, cannot be used very intuitively. It is essential to articulate voice commands clearly, even if this is not always easy in emergencies. Beyond that, the application should not constrain the user's actions through delayed inputs in extreme situations.

2.3. Research gap

Overall, it appears that HMD applications in a variety of safety- and time- critical contexts may both provide opportunities but, at present, come with significant limitations. Genaro Motti and Caine (2014) outline the human-centered aspects of HMD use, defining design (comfort, shape), purpose (functionalities), and usability as key elements. Accordingly, exploration is necessary to discover exactly which processes in the work of the emergency services need to be coordinated and supported, and which external factors are relevant. There are – as far as we know – no studies available which provide this information about HMDs in the specific use case of distributed emergency services on-the-ground. Related approaches in the domain of emergency management focus rather on the individual work of (medical) emergency services (e.g. Fuentes Fernández et al. 2014; Mentler et al. 2016), face-to-face collaboration around a table (e.g. Nilsson et al. 2011), or remote support

(Lukosch et al. 2015b; Poelman et al. 2012). No approaches are available which attempt to support cooperative work among emergency services on-site in highly mobile settings. The work context of Rescue Dog Units at the German Red Cross, therefore constitutes an exploratory design case study which might indicate both the potential use of HMDs in this kind of context and provide for a better understanding of how such applications are to be effective. The novelty of the resulting concept (section 5), based on an empirical study (section 4), will be compared to related work and highlighted in section 8.

3. Research question and approach

To answer the research question we outline above, how the work practices of mobile on-site units could be supported with hands-free and HMD concepts, we conducted a *design case study* (Wulf et al. 2011). A design case study consists of three phases: (1) an empirical study of current work practices in the field; (2) the development of innovative ICT artifacts related to the empirical findings, and (3) the evaluation of their usability and appropriation in practice.

Taking the current status of Google Glass into account – including its known (hardware) limitations (Lukosch et al. 2015b) and its global distribution – it is questionable if Google Glass is mature enough to operationally support this field. We know that Google stopped the project and the marketing of Google Glass 1 in 2015 (when a part of the study was already being conducted); however, not only Google Glass 2 (now called Glass Enterprise Edition) but also other devices such as Solos, Vuzix, Epson Moverio, Hololens, or Sony SmartEyeGlass are becoming more and more common and are actively being deployed in areas like healthcare and manufacturing. Thus, findings in respect of what features need to be embedded in HMDs for use in the context of emergency management (and elsewhere) remain relevant. Indeed, as such products become more common it is all the more important that their potential uses are adequately understood and contextualised.

The Red Cross – specifically their Rescue Dog Unit – was identified as a partner who engaged in cooperative and mobile practices to which they allowed us access. Performing empirical studies (section 4) led us to derive requirements for an approach which offers the handling of cooperative distributed search and rescue tasks using such technology and subsequently to design the concept of an application ('RescueGlass') that allows search tasks to be assigned to different mobile on-site units on a combination of devices, including smartphones and Google Glass (section 5). We implemented the functionalities, ran evaluations with Rescue Dog Units (section 6), and conducted a comparatives study (section 7). We discuss the results in section 8.

Our overall research framework is broadly inspired by Lewin's *action research* as 'comparative research on the conditions and effects of various forms of social action and research leading to social action' that uses 'a spiral of steps, each of which is composed of a circle of planning, action, and fact-finding about the result of the action' (Lewin 1958). This is a methodology appropriate for research in HCI (Hayes 2011). More specifically, our work is founded on observations in addition to interviews. The approach can therefore be characterized as 'ethnographic action research' (Hearn et al. 2008). In our case, 'planning' is equivalent to the empirical study of the given practices, 'action' focuses on the design and use of suggested ICT artifacts and the evaluation leads towards 'fact-finding about the results of the action'. This interpretation is also consistent with Hevner and Chatterjee's (Hevner and Chatterjee 2010) suggestion that action research should be integrated into design research. A *design science approach*, they suggest, consists of the design of an artifact for a relevant problem combined with rigorous evaluation methods for the design (Hevner et al. 2004).

4. Empirical pre-study of red cross rescue dog units

Our initial research comprised 42 interviews with various, mainly German-based, organizations involved in emergencies in relation to their use of ICT. This work demonstrated to us the need for a deeper consideration of this topic, and especially one which dealt with local circumstances (Ley et al. 2012; Reuter et al. 2015a). The Red Cross organization in Germany was chosen as the focus of this study because it exemplified aspects of time-criticality in particular. In addition to observations conducted during three dog rescue training sessions, we read descriptions of the processes of the Red Cross organization and further watched training videos that allowed us to observe and understand their work. Our study originated from a perceived need for a more detailed understanding of the work of Rescue Dog Units.

4.1. Methodology

According to Randall et al. (2007), ethnography is a form of analysis rather than a specific method. We adopted methods which provided us with as much realistic information as possible about the work. In fact, we adopted an informal group interview strategy, akin to focus groups, in the form of workshops.

Based on the first, exploratory workshop (M1, 04 June 2014, two hours, two researchers involved), we conducted two subsequent workshops (M2, 05 August 2014, and M3, 11 August 2014, each lasting three hours, with two researchers involved). M1 served as an initial exploratory talk to discover if there are in fact any possible use cases for HMDs in the field of the German Red Cross. M2 constituted a workshop to introduce the participants to smart glasses. Using the example of Google Glass as a possible new and relevant technological artifact for their work, participants were invited to consider ways of integrating it into their collaborative work practices. The most important initial finding was that the current work practice of the Rescue Dog Units is such that smart glasses, hands-free and HMD concepts could, in principle, make a significant difference in this context. We conducted a further workshop (M3) in which we could identify requirements for a possible application for the Red Cross Rescue Dog Unit. The results presented here are based on this third workshop (see Table 1 below).

Group discussions were audio recorded and transcribed for subsequent data analysis. The transcripts were open coded and the statements were divided first into text modules and later into categories. The knowledge previously acquired in the literature study was used to heighten *theoretical sensitivity* (Strauss 1987). Part of the approach involves *theoretical sampling*, meaning that we focused progressively on more specific areas as they were relevant to our research questions and required further analysis.

4.2. Results I: current work practice of the rescue dog unit

The work of Rescue Dog Units includes cooperative and collaborative tasks within and among different teams. Before a Red Cross Rescue Dog Unit mission starts (see Figure 3 below), the search area is divided into multiple grid squares to provide an overview of Rescue Dog Units. Each *dog handler* is assigned to one specific grid square together with his two helpers:

'The problem is that the search area is divided into three or four grid squares. Each dog handler is assigned to one square. It is important for the dog handler to see the part of the map he was assigned to so he notices if he accidentally leaves his area. At the same time, the person in the operation control car needs to be informed about that, too.' (P3).

The dog handlers are coordinated and supported by a technical leader who operates from the mission's control car, expanding group work in a spatial sense, and adding a communication element. The leader has up-to-date digital maps that he can access online and which he uses to organize the individual units (P5). Digital maps reduce the potential for dangerous situations; for instance, where roads are not documented on older maps. There is a specific approach to cooperatively search an area in a unit (P5):

Table 1. Participants of the German red cross.

Participant	Role	Meeting
P1	Head: Emergency Management	M2
P2	Deputy Head: Emergency Medical Service	M2
P3	County Head: Red Cross	M2 + M3
P4	Public Relations and Projects	M1 + M2
P5	Head: Red Cross Rescue Dog Units	M3
P6	Technical Head: Rescue Dog Units	M3

Figure 3.. Rescue Dog Units (picture: M. Münker, German Red Cross).

> 'What we do these days is as follows: There is this area here, X, that we have to search through und we always take two helpers with us for support. One walks on the left and the other on the right. The dog handler (walks) in the middle and the dog, which is sent by the helper, moves in a figure of eight shape between the helpers. So, you have an approximate area in which the dog can move.' (P5).

This cooperative work procedure, including the movement progress of the dog, is visualized in Figure 4 below.

While the assigned area is being searched, the dog moves freely and is not leashed.

> 'The dogs usually move between 30 and 50 meters to the left and right. When I walk through an area and send the dog searching, he knows how far he can move away. If you notice you have forgotten an area and the dog notices it as well, he searches the area again. You can see that pretty well if you watch how the dog moves and how he searches the area again.' (P5)

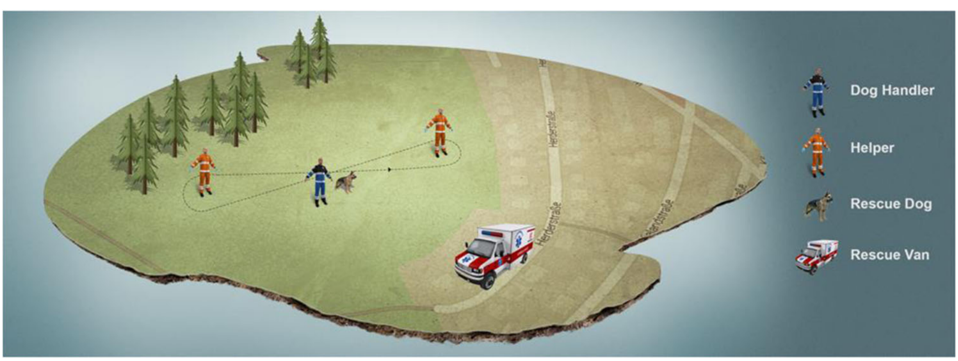

Figure 4. Current Work of the Rescue Dog Units (own illustration).

We can see that mutual understanding, agreement and reaction to signals is vital in effective cooperation between dog and handler. When an area has been scanned, the information is sent via radio and noted by the squad leader: 'If the dog handler thinks that the area was hard to scan, he reports it. But of course, you only have it marked roughly on the map.' (P5).

4.3. Results II: disorientation as a main problem – especially in unknown areas at night

Disorientation on the part of the units is one of the biggest problems encountered during an emergency mission (P5). If the area is not well known or has few distinguishing characteristics, it sometimes happens that nobody knows whether an area has already been scanned or not. This enhances the need for communication and documentation between and within units.

> 'The last two missions were at night. We wanted to do an area search and that means the whole area is searched, which is very difficult. You see a tree that has fallen down here and another one there, and then nobody knows exactly if they have already been there or not.' (P3)

It can be observed that many units get lost if difficult lighting conditions prevail in emergency missions (P3) and not even the support of conventional light sources is always helpful. Additionally, technical barriers to communication – such as having to combine devices from different producers or different software versions – lead to further problems instead of improving the process:

> 'A Rescue Dog Unit mission has the following problem: We work in extensive areas, one million square meters. Current practice is that the units arrive and we try to print maps […] so they walk around with maps. Sometimes it is pretty dark and you need a flashlight; the map is not one hundred percent accurate and not every team has a GPS device, because […] you have to transmit the data to the computer, and then there are the different devices and it's a huge effort.' (P6)

Due to the enormous size of most mission areas, some missions are delayed because the teams have to be briefed more than once. In addition to problems regarding the size of the search area and lack of light, uneven terrain is one of the dangers for the Rescue Dog Units, especially at night time:

> 'Or we simply go on a night mission again; we are often active in the Märkischer Kreis [a county]. If you often walk through the local woods, you know from

> experience that you will suddenly find yourself right in front of a deep chasm. It doesn't matter that much during the day, although even then you might have problems. However, at night, with only a flashlight, you can get into danger very easily.' (P6)

4.4. Results III: potentials and uses of glass – hands-free context-relevant information and collaboration of dog handlers

During the workshops, we introduced the participants to Google Glass. We wanted them to reflect on their own practices and to stimulate creative thinking about potential improvements and risks. An early recognition was that it is essential to localize one's current position during a search:

> 'When there is an area to be searched, you can identify both the area and my current position on the map. […] That would of course be ideal for the person searching through that area. Even better, he could locate himself and even check on the dog – see if they are both in the area where they are supposed to be.' (P5)

This would ease cooperative tasks and avoid additional efforts for communication, because this information would be easy to access. It also quickly became evident that any mobile technology had to display only information which is context-relevant and immediately required by each individual user. Google Glass must communicate with any smartphone being used, and related data has to be transferred to the operation control car where it is analyzed and displayed with the help of a computer. This kind of recapitulation is currently only possible while every person has reported that his area has been searched. More than this it would just been based on individual reports – with technical support it could be based on gathered data; and additionally individual reports. Not every member of an emergency unit requires a Google Glass; it would seem sufficient for only the dog handler to have one as he can profit from the hands-free concept and concentrate better on coordinating the dog. The helpers assisting the dog handler do not need a Google Glass as they can be supported by a smartphone application alone.

> 'What has everybody got in their pocket? A mobile phone with touchscreen and GPS. You could […] create an app which would mark the area for the Rescue Dog Unit on the computer. The teams would have it directly on their mobile phones and the phone could signal if they move outside the area. […] This should be possible with Google Glass as well so that it can tell you which direction to take, or that you are in the wrong place, or too far outside the search area.' (P6)

With this concept, mission areas could be made more accurate and safer. This applies to the user as well as to documentation and post-processing.

> 'On the one hand the effectivity of the area search when the dog handler sees that he is in the center of the search area and the dog is 30-40 meters away from the dog handler. If the dog handler now moves about 20-30 meters away from the middle position (to the left), the dog would do the same and could run into another search area. And I would also miss 20 meters on the right which would not be searched. On the other hand, the safety, the documentation of the mission via GPS interface that it will be tracked online; and you would be able to see faster where I still have to search' (P6).

4.5. Summary of empirical findings

The empirical study illustrates that a concept solely based on Google Glass is not adequate to the needs of a Rescue Dog Unit as a whole (section 4.2), but that it can be put to good use by the dog handlers. They need hands-free context-relevant information, including the position of other team members (section 4.4). Cooperation based on large areas is necessary and awareness could help to manage the situation among all actors involved. As disorientation is one of the main problems, any application should address this aspect (section 4.3). If members of the Rescue Dog Unit are already equipped with smartphones, they can use them as a resource (section 4.3), and an HMD application could be built upon this already existing infrastructure to provide specific functionality.

5. RescueGlass – concept and implementation

5.1. Challenges and derived design implications

Taking the empirical results into consideration, our concept for cooperation within Rescue Dog Units includes a shared solution consisting of Google Glass and a smartphone application so that information can be distributed as needed. Put simply, Google Glass forms part of an overall ecology and its functionalities have to mesh with those provided by other resources, such as the smartphone (P6). This approach corresponds with the statements from Tursi et al. (2014) who highlight the high potential of users as data sensors. Another factor is the available budget which does not allow the purchase of expensive devices for *every* person involved, but only for selected users (P6). Although expensive, using smart glasses is beneficial. We are aware that, so far, the use of Google Glass has not been fully established in any domain although we would argue that it continues to have potential (see details in section 3). Whatever potential may be realized over time, however, will depend on the degree to which a generic technology of this kind can be customized so as to fit the practical needs of users in specialized contexts. Accordingly, the aim of our study is not necessarily to design an application that explores the potential of HMDs within the context of on-site units in emergency management (see details on our methodological understanding in section 3) rather than providing a near-to-market prototype.

The application could, for example, show information about the mission directly in the field of view of the dog handler. This would enable them to retrieve information and communicate during the mission whilst still being able to keep the environment and the dog in view. The information could be GPS-data, sensors (e.g. metal) or data about the topology of the current area of operation (P6). As physical barriers and darkness often render missions very dangerous (P3, P6), it is essential to provide users with relevant information in a simple and clear way so that they do not have to deal with excessive demands (Funk et al. 2014). Furthermore, both approaches include the possibility of saving and documenting the mission data, which could then be shared among the members of the team. Improved technologies automate the process of documentation so that the effectivity of the subsequent analyzation is eased (P3).

Mutual awareness of relative positions among the helpers and the dog handler is an additional important factor that could be supported using wearable technology. At present, actors are not able to see their own position nor the positions of all the other people involved in the mission at the same time (P6). There can be little doubt that such awareness of location is significant in a number of broadly similar contexts, especially against the backdrop of team-based tasks. Ramirez et al. (2012), for instance, show possibilities for indoor tracking of firefighters in what are more extreme, but similarly time-critical conditions. Nilsson et al. (2011) state that this kind of location awareness between different units can lead to improved team-building capability and the reduction of difficult and ambiguous information processes. Additionally, according to an early survey study on wearable computing, 'context-awareness can improve user performance on information retrieval tasks' (Bristow et al. 2004). In keeping with this, according to Friberg et al. (2011), the need for high-quality information rises in accordance with the importance of the decision and action outcomes. Furthermore, related to the display of a map featuring current missions, a study on whiteboards in an emergency department revealed that 'coordination is accomplished through a highly intertwined process of technologically mediated visual overview combined with orally communicated details' (Hertzum and Simonsen 2015).

Our application RescueGlass (section 5.2) is designed with those general principles in mind. At the Rescue Dog Unit, the various difficulties encountered by helpers – such as the need to be briefed over and over again by other units – indicate precisely how information needs to be better structured and visualized with regard to navigation (P5).

5.2. Underlying concept

Based on our empirical study, we conceptualized RescueGlass, consisting of two parts: (1) an HMD application (implemented later with Google Glass) for the dog handler, and (2) an (Android) smartphone application for the helpers. The general idea of our HMD application is to assist Dog Rescue Units with navigation and location awareness support. RescueGlass provides hands-free interaction for the dog handler. This hands-free concept is necessary due to the more or less constant handling of the dogs. On both devices – Google Glass and smartphone – information is available about the mission (offline map of the target area) and both GPS-localization (visualization of one's own position and the positions of other team members; distance between the team members), and tracking (show and hide; recording and displaying; warnings when leaving the area and when there is too much distance between the team members) are made possible (see Figure 5 below).

It is important to note that RescueGlass is not a typical AR application that acts in a three-dimensional environment (Azuma 1997). It is a mobile application using HMD in addition to smartphones to display relevant information. The aim is to make use of HMD as a hands-free interaction concept, using different sensors.

5.3. Implemented functionalities

In the following, we describe how the concepts have been implemented, and present functionalities derived from the collaborative and cooperative work practices detected in our empirical study.

5.3.1. *Overview*

On the startup screen of the smartphone application (Figure 6a), the user can access a short mission statement in which the situation is described in a few brief words (Figure 6d). This can be compared to the short briefing before a mission that teams experience, but it can also support dog handlers and helpers during long-term search

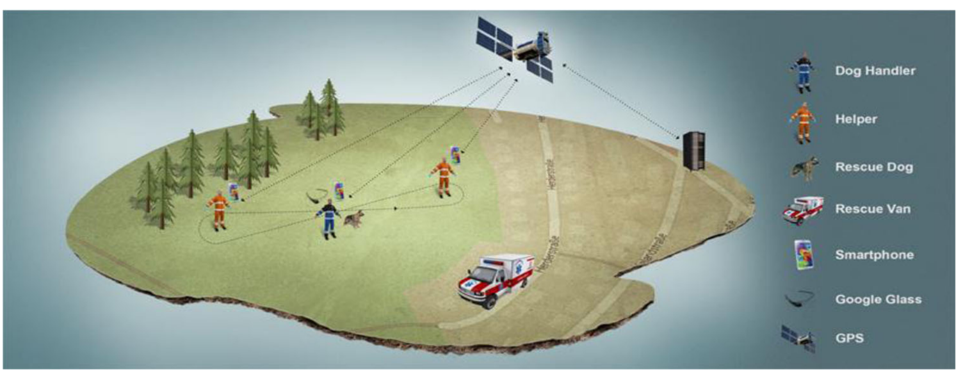

Figure 5.. Future Scenario including Google Glass and smartphone applications (own illustration).

tasks and shift changes. The short statement contains data regarding the missing people. Additionally, the user can access location-based data that contains GPS coordinates or an address. The mission map is the main part of the application. Before the map is loaded, the user can decide which team role he will have throughout the operation: 'helper', a role equipped only with a smartphone, or 'dog handler', equipped with a smartphone and Google Glass. The selected role will be connected to the localization data for documentation and analysis purposes afterwards.

5.3.2. *Map functionality*

The maps for offline usage are created with the Mobile Atlas Creator (http://mobac.sourceforge.net). The squad leader defines the area and creates a map of the target sector in advance. After selecting the appropriate role, the mission map can be downloaded (Figure 6b) in advance of the mission. Since this generally takes place in the operation control center or a similar gathering place, users normally have a stable internet connection and can download the map without data restrictions. As the map will subsequently only be updated with location information, it shows, from then on, where the team can currently be found. In future, the automatic pro-active download of a(n offline) map of the respective area seems appropriate (Reuter et al. 2015b).

Some light geographical information systems (GIS) functionality has been implemented inside the map, e.g. a zooming function enables the adjustment of the map to current needs (Figure 6c). Furthermore, dragging the map section allows the adjacent area to be explored. The distance to the other team members is always shown, thus guaranteeing that people move in a manner that ensures constant connection with the path of the rescue dog. If the area is left, appropriate warnings are displayed.

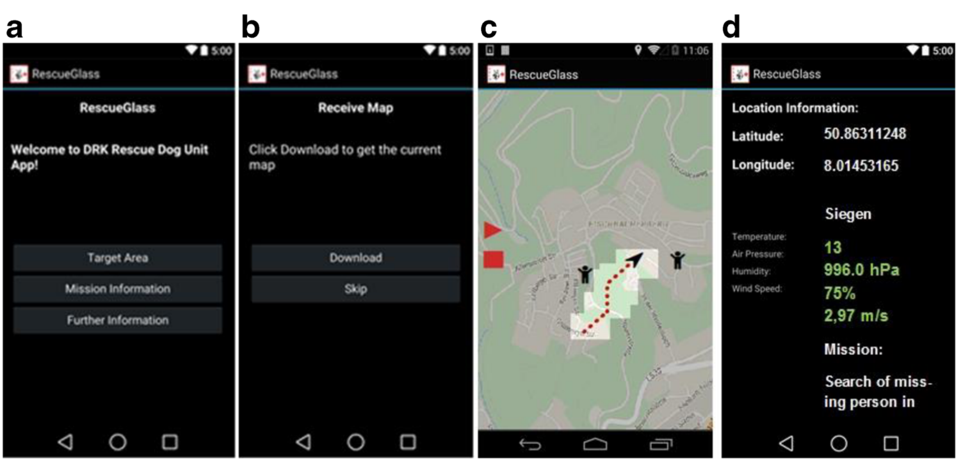

Figure 6. RescueGlass smartphone view: (**a**) overview, (**b**) receiving a map, (**c**) map functionality and fog of war, (**d**) mission and additional information (translated from German).

5.3.3. *Tracking, documentation, awareness, and fog of war (FoW)*

To analyze the emergency mission, a tracking function has been implemented that connects the location data with the role of a team member. The user can hide the tracking lines to aid orientation. Beside the option of displaying GPS coordinates, there is a function for analyzing them so that it can easily be checked whether the whole area has been scanned or if there are places that need to be gone over again.

In addition to the function which records, which paths the team take, a request was made for a facility to show areas that have already been searched. To realize this, awareness about one's own and other people's positions, real and historical, has to be created. To highlight areas that have already been searched, a 'Fog of War' (FoW) has been implemented. The FoW is a concept common in video games, mostly in tactic and strategy games (Darby 2009). Figure 6c shows a possible representation of the FoW effects. The user moves around on the map and can see which areas he has already searched whilst maintaining the visibility of the map section currently in use. As the map showing the current location has to be visible, a transparent representation of the hidden parts is appropriate. If the tracking lines offer too much information for the user, he can disable them without affecting the FoW. This functionality aims to address the disorientation mentioned in the empirical study.

5.3.4. *Further sensors*

The glass application, which also includes the mission note and map functionality, allows further sensor information to be detected, such as light conditions, metal detector and compass (see Figure 7 below). The metal detector is especially useful for the so called 'ruins group' – group to search in debris to save human lives endangered by earthquakes or the collapse of buildings –, as mentioned by the participants. Furthermore, warnings, as said in the section on map functionality, are displayed.

Figure 7. Rescue Glass HMD view: coordinates and own position (top); warnings ("Attention, nightfall"; "Metal near"), coordinates and address (bottom; selection that will be shown on the top corner of the view).

5.4. Intended collaborative use of rescue glass

The concept for the intended collaborative work of Rescue Dog Units is based on a Google Glass application and a smartphone application, which both work on the basis of the same data and provide similar functionalities. The main differences between those two devices are the view, the sensors of Google Glass, and the possibility for hands-free interaction.

While most communication is still using former protocols and is done in spoken form as well as using radio, collaborative views on the situation are the main collaborative feature in our concept. Here, collaboration works in the field of shared maps, in forms of having awareness where other colleagues are and in terms of FoW, to see which areas have already been searched. Furthermore, information about the mission is provided on both devices. This information is presented directly in the field of view of the dog handler, enabling him to retrieve information during the mission without losing the overview over the environment and the dog. In addition, the mission data can be saved, documented, and shared among the members of the team in time. This function facilitates the mutual awareness of relative positions among all participants, including the information about the role of each team member.

In providing all these functionalities, collaborative work can be enhanced, which is crucial not only for Rescue Dog Units but could be further developed for other emergency situations.

6. Evaluation of RescueGlass

6.1. Overall methodology

Despite our system having been fully implemented, we were prevented from running an in-use evaluation during actual emergency situations due to the security regulation concerns of the emergency response organizations. The evaluation of our overall concept and RescueGlass itself was conducted with a total of 18 users (PE1-PE18) in non-emergency situations. Our aim was to test both usability (E2-E4, with 10 ordinary people), and practice relevance for cooperative work, for which we enlisted professionals from Rescue Dog Units, mainly from the German Red Cross organization – the same group as in the empirical study (E1 and E5, with 8 professionals).

The evaluation was conducted over the course of four different meetings. The first meeting was a workshop that took roughly two hours and was held in the rooms of the German Red Cross organization (see Figure 8 below). All the participants were Rescue Dog Unit squad leaders or dog handlers. The subsequent meetings E2-E5 were held 'in-the-wild' in an open environment. The final step was to conduct individual walkthroughs and interviews with members of the Rescue Dog Unit (see Table 2 below). Each step took about one and a half hours, which is also the maximum length of a rescue dog unit mission. The whole process, from the test in the field to the following interview, took about eight hours. The discussions and answers to the questions were recorded and later transcribed.

6.1.1. *Methodology of the workshop (Evaluation E1)*
In E1, our primary concern was to identify whether the application would be used at all and, if so, in what ways; and what difficulties in use might be encountered. The philosophy behind the evaluation process was derived from the notion of 'situated evaluation' (Twidale et al. 1994) in which qualitative methods are used to draw conclusions about the real-world use of a technology involving domain experts. The intention here is not to assess the relationship between evaluation goals and outcomes but to derive subjective views from experts about how advantageous and relevant the technology might be in use.

The aims of the expert workshop were to explore whether the use of the concept would support work practices during an emergency and to identify the degree of acceptance of functions and of overall usability. After discussing the current situation, the concept for possible future practice was presented. Following this, we demonstrated the applications and the participants (see Table 3 below) tested them by themselves afterwards. Next, we gave them time to think about the concept in general and the applications.

Our questions addressed (1) the concept in general and the application including problems as well as usability; (2) good, missing or unnecessary functionalities; (3) the usefulness of the application and how it can be adopted in practice; (4) questions addressing concrete functionalities such as the FoW, the representation of the distance, use of the sensors on Google Glass (metal, light), voice control; as well as (5) general comments.

6.1.2. *Methodology of the field test (Evaluation E2, E3 and E4)*
The field test itself was divided into five phases. First, the project's background was explained to the participants to create a basic understanding of the idea of RescueGlass. Next, the scenario was presented to the participants and the devices were handed out. To test the application, the groups of participants had to reach a specific point (see Figure 9 below) – representing the missing person – by completing a scan of a previously defined area. They were instructed to track their own route as well as the one followed by the other participant. The scenario stated that two participants – one with the HMD application and the other with the smartphone – should walk through the area. During that time, the participants were observed by one of the researchers who accompanied them, thus allowing us to directly answer

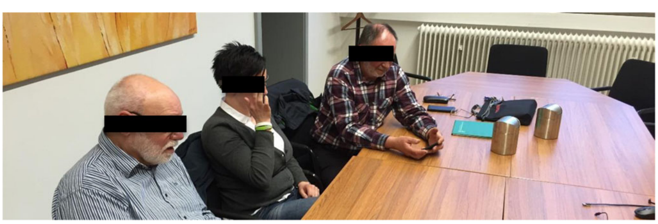

Figure 8. Evaluation - Expert workshop with Rescue Dog Units of the German Red Cross with smartphone (left and right) and glass app (middle).

Table 2. Evaluation sessions.

Evaluation	Description	Participants	Date
E1	Expert workshop at Red Cross (*n* =3, plus two researchers)	PE1–3	24 March 2015
E2	Field test I (*n* =4, plus two researchers)	PE4–7	27 March 2015
E3	Field test II (n = 4, plus two researchers)	PE8–11	28 March 2015
E4	Field test III (*n* =2, plus two researchers)	PE12–13	01 October 2015
E5	Individual walkthroughs and interviews (*n* =5, plus two researchers)	PE14–18	see section 6.1.3

any questions that might occur. After reaching the intended point, the role and the devices were switched. To create a variation, we decided to conduct the test at two different locations. In doing so, we differentiated between free and wooded areas. Afterwards, the participants were interviewed.

6.1.3. *Methodology of the individual evaluations (E5)*

The third part of the evaluation included individual evaluations with members of the rescue dog unit (see Table 4 below). The goal of the evaluation was to obtain feedback on RescueGlass in use. For this, it was important to consult experts in this field, and the work practices of Rescue Dog Units were taken into account for linking the results of use with fields of application. In addition to using the application, semi-structured interviews were also conducted. Throughout the interviews, notes were made on the most important statements and the interviews were additionally recorded to guarantee a more detailed analysis later. Questions included information on functionality as well as on strengths and weaknesses.

6.2. Results I: hands-free navigation system

Participants initially raised concerns about technical support during emergency missions. They were especially skeptical about the overall acceptability of these solutions and questioned their usability in emergency situations. However, the field test illustrated that the application has considerable potential for use in an emergency mission. The self-explanatory structure and the simple layout were emphasized. PE8

Table 3. Participants of the workshop evaluation (E1).

Participant	Role
PE1	Squad leader, dog handler, assistant paramedic
PE2	Dog handler, assistant paramedic
PE3	Dog handler, assistant paramedic

Figure 9. Evaluation – Field Test with smartphone and glass app.

even delivered a connection to a real use case in which a cluttered application would have a negative effect: 'I am in an extreme or tense situation and I do not want to be overwhelmed with a huge amount of interaction' (PE8).

Regarding voice control, largely positive comments were made (PE1, PE2, PE3):

> 'If I imagine: helmet, glasses, closed visor and gloves. And then you always have both hands on the leash. Then I have to take off my gloves and open the visor before I can operate it' (PE3).

Besides these positive views on voice control and hands-free-navigation, controversial opinions were also stated: in addition to their expensive price, the glasses were described as impractical as gloves had to be permanently taken off and put back on again in order to operate Google Glass manually (PE16). We therefore came across diverse points of view, partially based on the understanding of how to handle the device.

6.3. Results II: current features – FoW, map, compass, metal detector

Regarding usability of the mobile phone, participants generally did not see any problems. However, handling the glasses was considered inconvenient, and

Table 4. Participants of the individual evaluations.

Participant	Position	Role	Date
PE14	State representative for rescue dog work of the German Red Cross	Head of operations	03 June 2016
PE15	Presidency of the Rescue Dog Unit for fire departments NRW	Head of operations, dog handler	07 June 2016
PE16	Head of Rescue Dog Unit of the county	Dog handler	09 June 2016
PE17	Member: German Red Cross Rescue Dog Unit	Dog handler	09 June 2016
PE18	Member: German Red Cross Rescue Dog Unit	Dog handler	09 June 2016

participants suggested that the visualization of information should be simplified. The possibility to trace the path taken and to recheck the search area afterwards, exploiting the lines symbolizing the path and the FoW were nevertheless particularly positively emphasized. The ability to store the data was also mentioned as being very important.

> 'I think the FoW could be interesting for an area search. So that you really know, as a dog handler, there's a place where I have to look again more precisely.' (PE2) or: 'The FoW and tracking helped me because the map was marked and I was able to differentiate between the areas I had already been to and those I had not' (PE6).

FoW was used by the participants to make sure that they had checked the whole area. However, critical aspects of the FoW were also mentioned, because it is based on the dog handler and not the dog: 'Just because I was there this does not necessarily mean that the dog was there, too. I have to make sure that the dog really has searched the area' (PE15). Here we can see that technical support might help to generate relevant data as a basis, but individual reports based on subjective assessment of the situation are anyway necessary.

PE16 and PE17 recommended reducing the complexity of the application, suggesting it would only be necessary to display one's own area section and its borders: 'I just want to have the search area' (PE16).

Due to the precise tracking, it was possible to recognize even small changes in the route. Conversely, the FoW is resolved in a radius-based method, which does not necessarily represent reality correctly. Thus, PE8 stated that the radius of view should match the real field of view:

> 'The coloring of the map suggests that I am spinning around 360° and looking at everything simultaneously; instead it should be conical, a cone of view' (PE8).

The discussion at this point focused on the situation during emergency missions, already discussed earlier in our empirical study. One issue raised was that the Red Cross deploys helpers with heterogeneous skills in different situations which leads to problems, especially with helpers who are not familiar with the location of the emergency mission.

> 'Once we arrived at a kindergarten at night and the people did not even know that there was a kindergarten there. And they were familiar with the locality!' (PE1).

Additionally, PE15 mentioned that a map is not always available. Differences were also observed between theoretical processes and the actual practices whereby helpers were in charge of navigation but ultimately the dog handler essentially maintained overall responsibility:

> 'We don't always get a map from the police and if we don't have one, we just go without' (PE15) or 'The dog handler is only responsible for observing his dog. It's the helper who oversees that the dog handler and the dog get through the area safely […]' (PE15).

Furthermore, there were positive comments about the compass and the metal detector: 'The compass was easy to understand' (PE12) and 'I tested the metal detector. […] I approached metal objects and the potential uses became clear quickly' (PE12).

The display of information - such as time - was also praised:

> 'If a test is stressful, I would say the automatic display of information is very important. Otherwise users can easily take their eye off the time of day during the mission' (PE12).

On further experimenting with the Google Glass, another problem arose. PE17 noted that, although the field of view is not disturbed by the spectacle in the proper sense, concentration and focus are required if you want to "see" the contents of the glass clearly. However, in this case, the overview of the environment is lost and there is a conflict between the user's field of view and the Google Glass field of view. It is difficult to achieve peripheral perception of the information and thus the greatest potential benefit of the glasses is invalidated.

6.4. Results III: potential directions – collaboration, markers, and hardware

Other important comments covered functionalities that might be added later. One suggested feature was the opportunity to set markers on the map to enable the sharing of information between units. If a missing person was found, sending the pertinent information to the operation controllers together with the relevant map sector would be helpful. Another advocated function was the capability to access the contact details of all units involved in a mission.

Overall, participants proposed several possible new features, such as continuing tracking after leaving the map view, or the implementation of information concerning altitude for missions in mountainous areas. Two people criticized the lack of a caption or a short introduction inside the app.

In addition, collaboration plays a significant role. The head of operations has not only to coordinate the areas and the teams but also to communicate with both the teams and the police; yet software did not exist and was missed. Software currently available for keeping track of the whole team only supports tracking a maximum of ten people – even though strike forces might consist of up to 16 people (PE15).

In the case of subject detection, it is difficult to inform the head of operations about the find, the location and how to get there (PE15). Radio is usually used for this because calling someone on a smartphone would take too long (PE15). The interviews revealed the desire for a standardized reporting of the emergencies; currently, final reports are written with a word template that cannot be used for operations with Google Glass (PE14). PE6 stated that it would be important for his colleague to have a FoW on the map, too. Additionally, he encountered a problem during his task such that he was unable to inform his team member that he could not move forward due to the terrain. He described setting a marker on the map as a possible solution.

> 'It would have been good if I could have told my mate that there's a fence there so he knows, "ok, so I'll have to go a different way"' (PE6).

As we asked explicitly for missing features, PE4 and PE9 mentioned an altimeter for emergency missions in the mountains.

> 'I would have liked to have had an altimeter. If you're searching for someone in the mountains for example, it would be helpful to know how high you are at the moment' (PE4).

PE9 could imagine weather data being displayed on the map:

> 'It would be good to display information about the location on the map. In the settings, there was no option to display the temperature' (PE9).

Further challenges arose: Regulations for strike forces state that helmets must always be worn, which renders the use of Google Glass more difficult, particularly due to their lack of stability (PE14); and: The existence of safety helmets, protective gloves and the sometimes rough conditions during missions were not described in enough detail in the empirical study. This led to the statement that the hardware is hardly usable under extreme conditions and a form of Google Glass ought to be integrated directly into the helmets.

> 'The raindrops on the screen are a huge problem for me. […] In terms of hardware I see a real problem with Google Glass. It's just too delicate for what we do. We run through thick undergrowth at night' (PE3).

Some problems with the display of information were also identified:

> ‘While interacting with the glass, you concentrate on it and in doing so you don’t perceive the environment very well.” (PE11) or: “It can possibly take several attempts before you reach the desired functionality. With the glasses on, it was relatively difficult. You need to pay more attention on the forest floor while using the guide menu’ (PE12).

Problems with network coverage were mentioned, especially when the application was used in the forest (PE16, PE17): ‘Abundant vegetation in the forest can cause network problems’ (PE16). ‘In the summer months [we] always [have problems] [...] when the trees are covered with leaves’ (PE17). One proposal for addressing this issue was to connect the Garmin GPS navigation device to the Glass in order to show a reliable map on the Glass.

Overall, a variety of suggestions and observations were made which entailed the customization of Google Glass through apps which might provide a number of relevant functionalities and, additionally, about how best to integrate such apps with other technologies (such as smartphones). These included: (1) When interacting with the map, a distinction needs to be made between the head of operations and the strike force. (2) Hints about the duration of the operation could be beneficial so that the dogs are not overstrained. (3) Communication between the teams and the head of operations should be supported so that in emergencies everybody can react rapidly – without having to spend a lot of time calling people up. (4) The concept of integrating a facility for reporting was particularly appreciated.

7. Glass or smartphone? A comparative study

7.1. Motivation

Since several problems with the interaction approach of the Google Glass are already known, we aimed to further assess our results through a comparative study. Instead of focusing on smart glass, the focus was put on the accompanying smartphone application. This concept does not fully concentrate on hands-free interaction, but is an in-between solution: Here, the smartphone is strapped to the user’s forearm (see Figure 10 below).

It is possible to access the application without holding the device, however interaction is supported both with hand and speech, as supported by the smartphone. The idea was that this should enable the user to access information without holding a smartphone permanently in his hand. The smartphone was used as the transmission medium as we already knew from previous interviews that all rescue workers carried smartphones. Thus, in principle, this might make an alternative as a technology which is more cost-effective alternative to Google Glass and still is free-hand. The application is always available, and the emergency personnel can also access it easily in time-critical situations and under pressure. The key advantage is that they do not have to get their smartphones out of their pockets for every use. *PEASI* was selected as the acronym for this interaction approach. PEASI stands for "pervasive, easy access to smartphone information" (omnipresent, easy access to smartphone information) and includes the core elements of this approach.

7.2. Methodology

As a first step in the design, based on the empirical material presented in the sections above, paper prototypes were produced. Here, functionalities were adopted to enable comparison. These were made using the program "Balsamiq". In order not to complicate the application in the first step, it was decided to concentrate on the "area search" firstly (see Figure 11 below).

The evaluation of the paper prototypes was carried out with different persons. That did not involve members of rescue dog teams, but rather non-specialist persons with a medium to high technical affinity (PEP1-PEP5). From the results of the evaluations of the paper prototypes, a high-fidelity prototype was created with the program "Axure". For the evaluation of the prototype, the two use cases of the operation managers and the emergency personnel (dog handlers and helpers) had to be executed from beginning to end (HEP1-HEP5) (Table 5).

7.3. Results

Overall, the prototype was very well received by the rescue teams. They paid particular attention to its advantages, such as the easy handling or the fast access. The interaction approach PEASI was also well received. An interesting point, which has, however, emerged during the evaluation, is that rescuers felt that the app should not patronize or control too much. For this reason, the function of FoW was,

Figure 10. Interaction approach PEASI: pervasive, easy access to smartphone information.

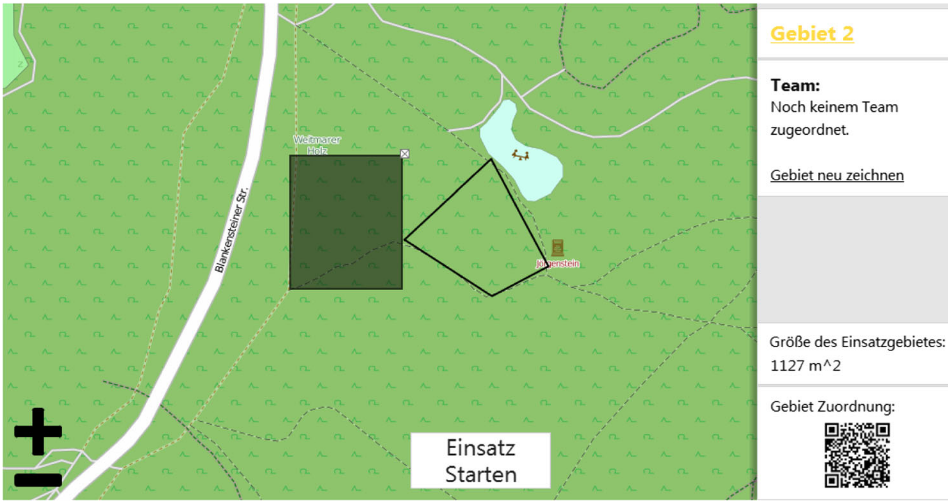

Figure 11. Prototype with the functionality of area search

somewhat surprisingly compared to our smart glass prototype, rejected. It was reported that the FoW would give a false sense of security concerning already searched areas since it was noted that the field of view differs in various terrains. Thus, in an open field, for example, one can expect a much larger viewing radius than in the dense forest. Therefore, one would have to adapt this field of view dynamically and / or make it individually alterable. Nevertheless, this was said to be too much effort for the small potential utility that this function would offer. It could be assumed

Table 5. Participants of the evaluation of the comparative study.

Participant	Position / Role	Date
PEP1	Backend developer	20 May 2016
PEP2	Quality assurance	21 May 2016
PEP3	Quality assurance	25 May 2016
PEP4	Consulting	30 May 2016
PEP5	Engineering	01 June 2016
HEP1	Presidency of the Rescue Dog Unit for fore departments NRW (Bochum) / Head of operations, dog handler	28 July 2016
HEP2	Member of the Rescue Dog Unit for fore departments NRW / Dog handler	28 July 2016
HEP3	Member of the Rescue Dog Unit for fore departments NRW / Dog handler	28 July 2016
HEP4	Head of Rescue Dog Unit of the county Siegen-Wittgenstein / Dog handler	09 August 2016
HEP5	Member of the German Red Cross Rescue Dog Unit / Dog handler	09 August 2016

that such functionality is not desirable because it overprescribes to the forces which areas they still have to search and which were to be "forgotten".

In addition to the newly designed app, the interaction concept PEASI was also presented. That is an alternative type of information representation. Instead of using the smartphone in hand, at PEASI, it should be attached to the user's forearm. That means that the application's information is available at any time for the emergency personnel and can be viewed immediately without having to use the hands. This free-hand interaction has already been considered important in recent studies (Fuentes Fernández et al. 2014). All users also received it positively and found it helpful.

HEP 4 and HEP 5, however, initially had several difficulties with the operation of the prototype. The display of the smartphone was considered too small, and it was suggested that, perhaps, a tablet or laptop might be better (thus obviating the point of the 'hands free' design). In addition, several functionalities were overlooked; this could also be seen as a hint that the display of a smartphone is too small for an operation manager. A clear assessment to whether an application based on Google Glass or smartphones would be more effective, could not be made. It is our view that this represents in large part the fact that Google Glass at that point, while it had potential, could not be directly applied in this safety-critical area until and only if design obviated some of the problems.

8. Discussion

The field test of RescueGlass revealed some challenges for the developed prototype: the participants mentioned some minor visual aspects as well as a problem with the performance of the application. Currently, the hardware was (and still currently is) not feasible and is too 'delicate for what we do' (PE3). Issues regarding robustness and reliability in circumstances of extreme weather or unusual terrain are of high importance and potential enhancements that might be made have been discussed. For us, it was not only important that our design was "good", but also that it allowed us to research the application field and possible use of technology through our design (Zimmerman et al. 2007).

Based on the results of our proof-of-concept as well as a comparative study, we are able to discuss lessons learnt and to present general guidelines for designing approaches for collaborative HMDs in the field of emergency services – especially when dealing with on-site mobile units – that are of interest to other HCI designers and software developers:

1. *Integration of tools*: To exploit the potential of HMD applications in collaborative scenarios while recognizing that different roles mean there is no need to equip all members with novel and costly technologies, we suggest building applications that are integrated within other existing IT infrastructures and tools, or are at least strongly linked to them – e.g. in combination with (cheaper) smartphone-based applications. In our case, the dog handlers themselves were subjected to conditions which indicated the usefulness of

Google Glass although this was not the case for the helpers. A combination is therefore both reasonable and less expensive. It also is important to consider the human barriers that exist in the use of a new technology. Although mobile phones are familiar to everyone, smart glasses are new and imply a learning curve, thus giving rise to variations on existing practices.

2. *Playful innovations:* With the Fog of War we have applied a well-known concept we derived from games (Darby 2009) to support awareness in collaborative work. The concept was perceived well and we assume that rescue units are more willing to take gamification aspects into their daily business. Contrary to this, the comparative study revealed there is also resistance against this function when implemented on a smartphone; therefore it should be an optional functionality. As the collaborative work practices can be compared to those practices of games – and vice versa – using selected well-known concepts from playful spheres seems reasonable.
3. *Technology maturity:* While designing collaborative systems and services in general for the domain of emergency management, it is important to recognize that some aspects of the usefulness of any given technology might relate to its maturity. Version 1, so to speak, may have consequences in terms of rarity, time pressure, uncertainty and complexity but these may be resolved at a later date. Additional functionality, nevertheless, needs to relate directly to requirements for outdoor activities that might occur and which, in some circumstances, might be considerably more extreme (Mendonça 2007). Likewise, potential network breakdowns and other problems need to be taken into consideration. In our case, we found that the hardware (Google Glass) seemed interesting during our lab experiments but was not yet mature enough to fulfill all practical requirements, and other affordable tools are not yet available. However, they are about to appear. New versions of Google glass, mentioned above, seem to be more explicitly geared towards professional environments and thus some of the difficulties we have discussed may be resolved. Indeed, one can regard internet networks as 'immature' in some sense, since it remains the case that coverage is spotty at best in many rural areas. Nevertheless, evaluations of existing technology need to be more than simple 'snapshots'. They should point the way in terms of possible future improvements as well. While it is at least questionable whether this technology will be introduced 'as is' to the field, our experiences can be used to design supporting tools based on more mature hardware in the near future.
4. *Extension of technology usage:* While AR provides interesting possibilities for HMD applications, it is important to base it on requirements and work practices in a way that irrelevant considerations can be avoided. While we acknowledge that Google Glass does not provide a full AR implementation, within our study the interviewees mentioned avoiding gimmicks and the need instead to remain focused on their main work practices. The aforementioned Fog of War was not seen as such a gimmick. We know that the possibilities of the hard- and

software are not currently maximal (e.g. AR features). However, we believe that the success of services and systems (not just) for emergency management depends on the fulfillment of user needs, not on the amount of technology usage.

5. *Data usage:* Although avoiding disorientation and providing hands-free navigation were the two main requirements for use while tracking movements, other uses for the captured data (positions, movements, conditions, light and metal sensor) in later phases of the emergency management cycle arose. These include the subsequent documentation of all actors in this collaborative setting, which might be enormously eased by the availability of this data. This has ultimately been rated as one of the key features.

9. Summary and conclusion

The 'death' of Google Glass was widely reported after Google reported that it would stop selling the 1st version in 2015. In fact, development has continued and in July, 2017, Google announced that Google Glass Enterprise was soon to become available. What became obvious was that the original purposes envisaged for the technology, which largely had to do with adoption by generalists, was not going to happen. This was a result of various concerns which had to do with cost, safety, privacy, 'geekiness' and so on. It did not follow, however, that the technology would fail in more functional environments. Much of what we report on above in terms of the available literature and our own work support the notion that the potential for wearable technologies of this kind remains high.

Our article uncovers the highly cooperative work practices of on-site emergency service teams that consist of a constant mix of routinized and non-routinized activities. The on-site units have to deal with several uncertainties regarding the involved dogs, the fragility of the respective situations as well as issues of using technologies under enormous time pressure. With our article, we explore the collaborative potential of smart glasses in such time-critical and uncertain situations. We have designed and implemented RescueGlass as a Google Glass based concept to support the cooperative work practices of the German Red Cross Rescue Dog Units, and revealed findings related to the evaluation of a HMD application in collaborative settings. Our contributions are largely empirical, including recognition that the hands-free features of smart glasses would be particularly useful for dog handlers, while helpers could use the corresponding application with (much cheaper) mobile phones. While reviewing related work, we did not find any existing literature concerned with the use of HMDs for the support of such highly cooperative work practices within uncertain situations. This allows us to address a novel – although mainly exploratory – research question, which focuses on the potentials and challenges of using HMD concepts for Rescue Dog Units.

We have examined the extent to which existing concepts for emergency coordination can be used to establish technical solutions in the process of a rescue mission. We applied research strategies involving ethnographic field studies to the use case of the Red Cross's Rescue Dog Units. Taking Google Glass as the leading contemporary technology (at least in 2015 when we conducted large parts of the study), and we examined existing concepts such as Steve Mann's Generation Glass (2012b).

After conducting an empirical study in the field of the German Red Cross organization, possibilities for the use of smart glasses were identified. We argue that a concept based solely on smart glasses is not suitable for use with Rescue Dog Units but rather only a concept using Google Glass in combination with smartphones seems appropriate – not least due to financial issues. This led to 'RescueGlass' being developed – a concept for a mobile localization application for the coordination of distributed Rescue Dog Units. RescueGlass was subsequently realized as a prototype fulfilling the following features:

1. Hands-free interaction for the dog handler using the Glass application;
2. Information about the mission, e.g. task, conditions, location;
3. Cooperation with GPS-localization: visualization of one's own position and the positions of other team members; distance between team members;
4. Tracking: show and hide; recording and displaying; warnings when leaving the area and when there is too much distance separating team members; Fog of War to display areas that have already been searched;
5. Simple and straightforward use even in extreme conditions.

Finally, we tested RescueGlass in a three-phase evaluation. Firstly, we tried its feasibility in a field test in the wild. Subsequently, we evaluated the application and its underlying concept by using experts following scenarios applicable in the field of the Red Cross. We also conducted individual evaluations including interviews with members of the Rescue Dog Units. As the field test showed, the application harbors potential for emergency missions in relation to its feasibility. The self-explanatory structure and the simple layout were especially emphasized as being valuable. The usability of the application in a stressful and dynamic situation requires careful analysis of the way in which humans and their work practices interoperate with technology.

Specifically, technologies, which impose a burden or cause additional stress by restricting movement or causing a delay, are not appropriate. Ease of use and hands-free interaction are critical here. Besides these two factors, the core functionalities, like tracking and playful approaches such as the FoW, were also described as being important and helpful: 'It is important that I can recognize later on which way the person went and where my dog was' (P1). This functionality is not just potentially interesting for Rescue Dog Units, but may well carry capacity for other mobile and cooperative application areas focusing on situational awareness for spatially distributed teams.

We have demonstrated that our design case study resulted in (1) requirements, (2) the conception of an HMD and smartphone application for Dog Rescue Units, and (3) its evaluation, which provided qualitative empirical results (with a total of 18 participants) as well as technical contributions (RescueGlass prototype) in addition to lessons learned for the use of wearable technology in the form of smart glasses during emergencies. Furthermore we have conducted a comparative study including an evaluation with 10 participants.

Compared to related work, neither the HMD-applications for collaboration between emergency services (Nilsson et al. 2011) nor the AIRCacher (Tursi et al. 2014) have the functionalities at their disposal which our respondents deemed to be important, such as the opportunity to mark locations already visited area-wide. Fuentes Fernández al.'s (2014) application for the triage of accident victims for the Red Cross and Wu et al.'s (2013) interactive checklist provides comparable results. Lukosch et al. (2015b) focus on remote annotation. At the same time, the concept of data storage implemented in the prototype has high potential for the subsequent analysis of emergency missions, and this was previously not possible: 'You have it documented. Afterwards, you can deliver the documentation to the operation controllers digitally' (PE3).

There are undoubtedly some limitations to our study:

1. We used the technology of Google Glass even though we were aware that it might not be mature enough from both hardware and a software perspective. However, we argue that it is ready to allow us to explore the potential of HMDs for our specific application area.
2. The sample of our evaluation was rather small ($n = 18 + n = 10$ in the comparative study) and our application, RescueGlass, has not yet been evaluated in operational use during an actual disaster (German Red Cross regulations prevented us from having an in-use evaluation during actual emergencies, but allowed it during training sessions). Nevertheless, we think we were able to derive some lessons of interest for researchers and practitioners in the field of CSCW and HCI.
3. Furthermore, the application does not make full use of various AR concepts. We argue that this is in accordance with the requirements of the participants of our study, who explained their desire that their most important needs should be focused on in relation to their HMD application and the need to avoid 'gimmicks' such as 3D layers or pictures from on site.

Various directions are indicated for future work. As mentioned in the evaluations, more robust technology than Google Glass is needed for use in actual emergencies, one which may well be provided as the Glass Enterprise edition is more fully developed. As we have intimated, Google Glass has become regarded, somewhat inaccurately, as a failed technology. Its application for professional purposes has been examined, as we have pointed out, but relatively little work has been done on the way in which new versions might mesh with the demands of outdoor, time-critical, sometimes extreme conditions. Our study is an exploration of how we might approach such possibilities.

Within our study, the aim was firstly to use novel HMD approaches to support collaborative work practices within Rescue Dog Units. Using smart glasses within these fields is a novel design probe; as the first step, we wanted therefore to gain qualitative insights and generate hypotheses regarding potentials and obstacles of HMD concepts within highly collaborative and mobile work settings and if as well as how a proposed prototype could be designed. From our point of view, qualitative feedback using qualitative methods was therefore necessary. In the context of future work, we plan to enhance our study by using a quantitative evaluation for testing our hypothesis across a considerably larger number of users.

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