Supporting first responder in-field communication and navigation using head-mounted displays

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ABSTRACT

This paper explores the added-value of using interactive head-mounted displays to support command and control of first responders during emergency response. Specifically, it describes and evaluates a prototype system that makes use of Google Glass to enable in-field receiving of information from a command center, as well as in-field navigation and video streaming. The viability and usefulness of the concept was evaluated through a set of end-user workshops and interviews. A small-scale experiment was also conducted to assess the efficiency of using head-mounted displays for in-field navigation, as compared to handheld devices. Findings from workshops and interviews suggest that head-mounted displays could be a valuable supplement to radio communication, with potential for reducing information misinterpretation, and for enhancing information quality. Results from the experiment indicate that head-mounted displays have the same level of efficiency as handheld devices when used for basic navigation tasks.

Keywords

C2, communication, emergency management, head-mounted display, navigation

INTRODUCTION

Efficient communication is an essential key to the successful handling of emergency situations, but also one of the primary challenges (Manoj and Baker, 2007). Almost without exception, after-action reports from large-scale emergencies point at inefficient communication as a primary cause for failure in emergency response (NOU, 2012). According to recent research, one of the main barriers hindering efficient communication is the limitations that come with the use of radio as the only means of communication (Eide, Halvorsrud, Haugstveit, Skjetne and Stiso, 2012). Often, radio networks have limited capacity, allowing only one person to speak at a time. Depending on the radio system in use, information may also be sent out to all parties, causing information overload in an already chaotic and stressful environment. Certain types of information, such as directions, can also be quite difficult to convey using voice only.

Drawing on the abovementioned challenges, there is a clear need for technologies that can help improve communication during emergency management. One option for this is to equip first responders with handheld devices such as smartphones or tablets, allowing easy sharing of images, videos, text and maps. This concept has for instance been applied to facilitate the sharing of a common operational picture

(Milanes, Stevens and Alford, 2014). One catch with the use of handheld devices is that emergency responders typically need to keep their hands free for field work, making interaction cumbersome, time-consuming, and difficult. Previous research has also been done comparing the benefits of using head-mounted displays with conventional display technology (Minnich and Schell, 2003).

This paper introduces and evaluates a prototype system that uses Google Glass, an optical head-mounted display, to support command and control of first responders during emergency response. The prototype, which is currently in an early phase of development, is first and foremost designed for use by first responders from the police, enabling receipt of information such as text, images and map directions on a small display connected to a pair of glasses worn by the responder, allowing hands-free interaction. The prototyped concept is not meant as a replacement to the use of radio, but rather as a supplement that can help mitigate some of the challenges connected to communication during emergency management.

The design and development of the concept followed an iterative, user-centered approach involving several participants from the Norwegian Police forces. These participants took part in interviews and surveys to help identify user needs, and to determine the usefulness and feasibility of the concept. A small-scale experiment was also conducted to assess the navigation functionality of the concept. The remainder of this paper describes both the prototype and the results from the surveys, interviews and experiment that were conducted. A discussion and conclusion regarding the feasibility of the concept is also provided.

END-USER SURVEY

Initial interviews with police personnel showed that the head-mounted display solution should support the following main features: receipt of text briefs, map navigation, sharing of images and video streaming. Based on these results, a survey was conducted to help prioritize the perceived usefulness of the identified features. The survey was conducted at the Norwegian Police University College, involving 103 participants. The results presented in Figure 1 show that features for using text, images, maps, as well as remote guidance were considered useful by the majority of participants. The map feature was found useful by all 103 respondents, and should therefore have a main priority. Additionally, the survey included questions about current communication tools, which the majority of the participants thought to be efficient. However they also agreed that the proposed additional features could increase efficiency significantly and 73% stated that they were positive towards use of head-mounted displays in their work.

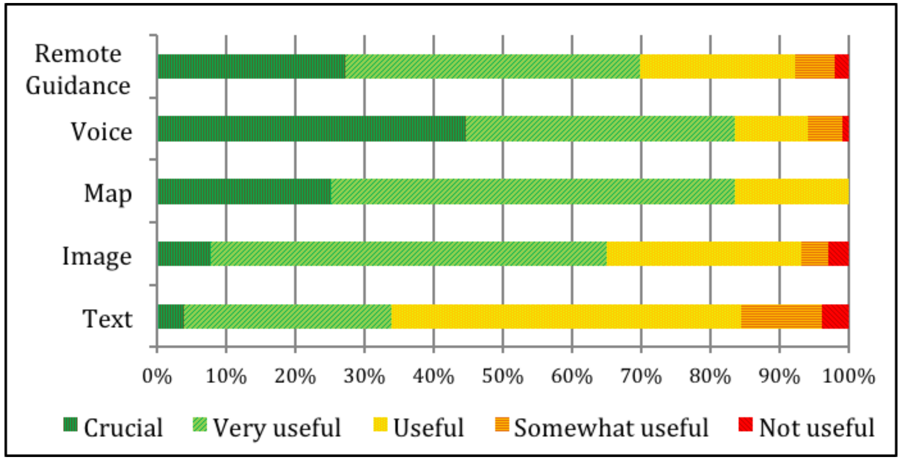

Figure 1. Results of user survey

CONCEPT AND PROTOTYPE

The prototype was implemented for the Google Glass wearable device (see Figure 2). This device includes an optical head-mounted display (1) (640×360 pixels), Bluetooth and Wi-Fi connectivity, an internal storage and a camera (2) (5-megapixel, capable of 720p video recording). It can display information similarly to smartphones, and can be controlled by voice commands or gestures using a touch panel (3) on its side. Additionally, it is capable of connecting to mobile data networks through any Bluetooth-enabled smartphone with a data connection. [1]

Based on the feedback from interviews and surveys, a primary design for the prototype was developed, presenting a concept of the relevant features and how they may be implemented. The general idea is to allow command center personnel to relay relevant information related to a specific mission using text or images that would automatically appear on the screen of the field operative. The prototype integrates navigation instructions and geo-localized information displayed on maps. Live video streaming, using the built-in head-mounted device camera, can be enabled by the responder, providing a real-time video stream of his/her point of view to the command center.

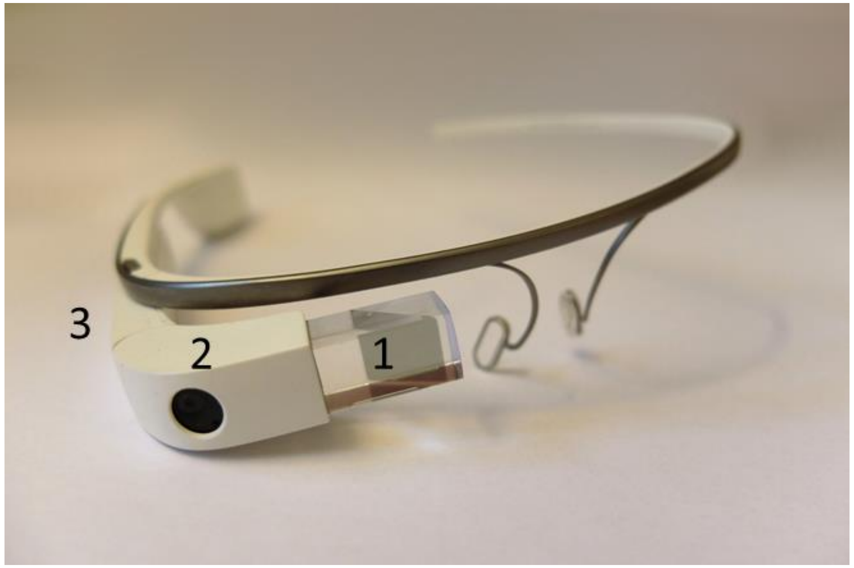

Figure 2. Google Glass

[1] Google Glass Tech Specs:
https://support.google.com/glass/answer/3064128?hl=en&ref_topic=3063354

The user can access the application through the main Google Glass menu. When launched, it will continuously be able to receive mission data from a command center. Once the user accepts the mission, more details are provided to the user through a "mission screen". Depending on the nature of the mission, the mission screen will display the appropriate form of information. For example, for a search and rescue mission, an image of the person(s) to be rescued would be displayed on the screen to aid recognition. Similarly, if the location of the target was known, a map will be displayed on the mission screen, guiding the user to his/her destination. The user can browse through all of the information he/she has received on a particular mission as well as navigate through the prototype features, using gestures and voice recognition.

The basic Google Glass interactions consist of four gestures applied on the side touch panel: swipe forward (to scroll forward or downward in a menu), swipe backward (to scroll backward or upward in a menu), tap (to open menu or select a menu item) and swipe down (to exit the current menu). A fragment of the design structure of the application, based on Google Glassware Flow Designer, is shown in Figure 3. The system was designed to be simple and intuitive, eliminating extra menu items, for maximum ease of adoption and use.

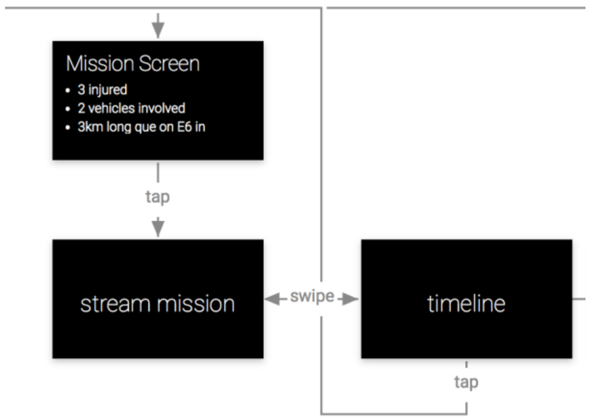

Figure 3. Clip from the prototype menu flowchart

To test the concept, a simple prototype application was developed and installed on a Google Glass device, implementing a set of sample mission briefs, relevant images, and map directions, displayed as it would be during a real mission.

From a hardware perspective, the physical robustness of the Google Glass in the context of use by emergency services is a potential shortcoming which may need to be addressed through further research and development. Additionally, compatibility with other equipment being used during operations may also entail operating challenges.

Introduction of this technology may also affect the flow of information between the operatives and the command center (Orlikowski and Robey, 1991). For example, information that would normally be communicated through radio may be summarized in condensed text form or with the help of images/maps. This would require additional actions from the command center and may also involve modifications to the command center technology/interfaces.

From an ethical perspective, the video streaming function of the application may be subject to legal scrutiny. Further consideration is required to address the intended and unintended consequences of this technology (Winner, 1980). In an emergency situation, there will always be spectators and others who are within the zone of the operation, leading to them being included in any video recording that is made during an operation. As there is no practical way to gather prior consent from the concerned individuals, new legislation would therefore be required, empowering the police force to use this technology. The legislation would also need to take into consideration details of situations when such recordings would be justified, how the data would be stored, and for how long.

METHOD

To test the usability and application of the prototype, several methods of evaluation were considered (Lazar, Feng, Hochheiser, 2010, p. 252; Rogers, Sharp, Preece, 2011, p. 490). End users were given access to a high fidelity prototype, as seen in Figure 4, followed by open-ended interviews to assess user experience. A simple experiment was also conducted to test one of the features, the map function, where the efficiency of using map navigation through the head-mounted device was compared to the efficiency of following the same directions on a smartphone. The experiment required each participant to follow a route around the Aker Brygge area in Oslo, Norway, while the time taken to complete the route using different devices was measured and recorded.

Figure 4. Police personnel evaluating prototype

The null hypothesis for the experiment was that regardless of whether a user is using a head-mounted display such as Google Glass or a smartphone for navigation, they will use the same amount of time to complete a given route. The alternative hypothesis was that using a head-mounted display such as Google Glass for navigation results in less time used compared to using a smartphone.

Our only independent variable was the device used to complete the route, and the dependent variable was the time it would take to complete it. Because there was one independent variable, and two conditions, a between-group experiment was conducted. Two groups were used, where each group was performing a task with only one condition. The design of the experiment focused on avoiding the learning effect, which could greatly affect the results. To limit the individual differences that may stem from a between-group experiment, the recruitment of participants was from a pool of individuals with similar jobs and within a similar age range. None of the users lived or worked in the area of the experiment, thus limiting their previous knowledge of the area. A within-group experiment could have been conducted with the same users and by randomizing the order in which the participants were assigned to the conditions. However, due to there being only one route to be completed, the results would be greatly influenced by the knowledge the participants would gain from the first time they complete the route, regardless of which device they use.

The route was pre-set on the Google Glass or the smartphone before the user was given the device. The facilitators involved in conducting the experiment were not allowed to answer any questions from the participant throughout the experiment, and the users were only allowed to use a normal walking pace. This was clearly communicated to the users before the experiment began. Each user, from our pool of 12 users, was randomly assigned either a mobile phone or a Google Glass. Standardized instructions were used by all facilitators with no participants receiving more instructions than others, limiting the likelihood of biased results.

The experiment was spread over four days at roughly the same time of day (between 11 am to 2 pm) with similar weather conditions (no precipitation, and temperatures between 5-10 °C). The expressions of the users throughout the experiment were noted, and a mini-interview was conducted to ask the users about their experience.

An additional aspect that could be considered is “inattentional blindness” which leads the user to focus more on the information displayed on the screen, rather than events in their environment (Krupenia and Sanderson, 2006). It could be interesting to separately record the amount of time the user spends looking at the screens, compared to the time spent looking around at the surrounding environment, for both devices.

RESULTS

The results from the experiment as given in Table 1 show the time taken to navigate through the given route for each participant. The participant ID's are coded such that all usernames starting with "G" refer to users that were using Google Glass while those with "M" refer to users that were using mobile phones. User expressions are grouped into two categories where the users seemed either 'confident' or 'frustrated' during the course of the experiment. All users not displaying frustration are considered to be ‘confident’. As shown in Table 1, the times taken do not vary significantly between the two groups of participants, indicating that our null-hypotheses may have been correct.

User	Time (s)	Frustrated	Confident
G1	26.23	No	Yes
G2	22.03	No	Yes
G3	24.37	No	Yes
G4	23.44	Yes	No
G5	24.39	No	No
G6	25.09	No	Yes
M1	22.54	No	Yes
M2	25.50	No	Yes
M3	26.22	No	Yes
M4	23.27	Yes	No
M5	24.56	No	Yes
M6	26.02	No	Yes

Table 1. Results of experiment

Despite the fact that the experiment involved few participants, it was still decided to conduct a statistical analysis to further analyze the results. Since initially a difference was expected in the results from the two groups, an independent-samples t test was deemed appropriate. Moreover, the sample was found to be approximately normally distributed, validating the use of a t test.

Table 2 shows the results from the t test performed on the collected data from the experiment. By definition of the t test if t Stat < -t Critical two-tail or t Stat > t Critical two-tail, the null hypothesis can be rejected. As this is not the case with the results, the null hypothesis holds, while the alternative hypothesis must be rejected. This means that no significant difference was found in the time used to navigate a route using a head-mounted device vs. using a mobile smartphone.

	Variable 1	Variable 2
Mean	24,25833333	24,685
Variance	2,048816667	2,28431
Observations	6	6
Pooled Variance	2,166563333	
Hypothesized Mean Diff.	0	
df	10	
t Stat	-0,502069279	
P(T<=t) one-tail	0,31324427	
t Critical one-tail	1,812461102	
P(T<=t) two-tail	0,626488539	
t Critical two-tail	2,228138842	

Table 2. Results of t test

Based on the observed expressions, there was no relation between how much time one used on the route and the overall experience of the use of the different devices during the experiment.

Due to only 12 users participating in the experiment, the results should be regarded only as indicative with respect to the hypothesis. Further validation using a larger set of participants is required to confirm the findings. An improved test scenario could include additional tasks in which the users have to use their hands, testing the "hands-free" design of head-mounted devices. The navigation could also be tested in different environments, such as indoor, urban, maritime or forests. Ensuring that all participants are probable end users could further increase the validity of the experiment, providing results specific to the target group, i.e. the police force.

From the interviews, one very important factor was pointed out by a high ranking official of Oslo Police District. He said that, "To make this a product that is actually used by the police, it needs to be as simple and as intuitive as possible." All the clutter and extra menu items should be removed, keeping only that which is necessary. He, as many others, also mentioned his concern about the physical robustness of the Google Glass.

DISCUSSION AND CONCLUSION

The results from the project so far indicate that use of head-mounted displays with features such as text briefs, image sharing, maps, and remote assistance have the potential to improve communication between field operatives and command center personnel. These features could for instance reduce the likelihood of messages being misinterpreted and enhance the quality and detail of the relayed information.

However, whether implementing these features through a head-mounted device is a feasible solution still remains a question. Results from the presented experiment show that both the smartphone and a Google Glass device provide a similar level of efficiency for a basic navigation task. This suggests a potential efficiency gain from using a head-mounted device in a context where the user is required to keep his or her hands free for any additional tasks. This is somewhat in line with earlier research showing that a supplement head-mounted display could be useful when navigating with a GPS-receiver in an unknown environment (Hellgren and Johansson, 2012), and research showing that technologies such as GPS, digital maps or electronic compasses can improve the ability to precisely indicate directions to objects (Johansson, Hellgren, Oskarsson, and Svensson, 2013).

Additionally, more practical issues need to be looked into. The robustness of the device must be considered. For tasks related to emergency operation, the device must be capable of tolerating impact, humidity, precipitation, extreme temperatures and other harsh conditions. Further, as the concept requires connectivity between two or more communication units, the connectivity must also be seamless in an emergency situation. Currently, the connectivity is based on 4G data traffic provided through available mobile networks which may not cover all the required areas, such as remote and underground locations. The wearability of the device may also play a part in its utility. Although the tests described only cover the use of the device for shorter periods of time (less than one hour), users may find the device to become intrusive in their field of view, or cumbersome to wear, especially when used over longer periods of time. Further research is therefore required to truly validate the benefits of using head-mounted display to support communication in emergency management.

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