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Original research

Medical applications of near-eye display devices: An exploratory study

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HIGHLIGHTS

- We present a framework to identify and categorize use cases for Google Glass.
- We describe the use of Google Glass during a radiological intervention.
- An app was developed to project vital physical signs to Google Glass via intranet.
- Interventionalists reported improved concentration by reduced head movements.
- However, heat generation by the device and low battery capacity are shortcomings.

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ABSTRACT

Introduction: Near-eye display devices (such as Google Glass) may improve the efficiency and effectiveness of clinical care by giving clinicians information (such as the patient's vital signs) continuously within their field of vision during various procedures. We describe the use of Glass during a radiological intervention in three patients. Other possible applications (including tele-mentoring and the supervision of trainees) are discussed and a classification proposed. **Methods**: An app was developed to facilitate the use of Glass, so vital physical signs (pulse and blood pressure) could be projected on the near-eye display, via an intranet to protect sensitive data. The device was then used during radiological interventions (percutaneous transluminal angioplasty) in three patients, and assessed by the interventionalists who were interviewed before and after each procedure. **Results**: The interventionalists reported that Google Glass improved concentration on the task in hand by reducing head and neck movements (which would be needed to view several remote monitors). However, heat generation by the device and low battery capacity are shortcomings for which solutions must be developed, and data protection is mandatory. **Conclusion**: Google Glass may have a number of clinical applications and can quicken interventions where vital signs or other visual data need to be monitored by the operator.

1. Introduction

A near-eye display device such as Google Glass enables the transmission of information by augmenting visual perception via a projection in the field of vision. This consolidation of information can potentially allow improved situational awareness without distraction from primary tasks.

Although near-eye display devices or so-called optical head mounted displays (OHMD) have existed for more than four decades (e.g. [1–3]), the development of Google Glass (from now on we call it Glass) has created excitement about the potential process improvements that might come from using such devices in a clinical setting [4,5]. Some research groups tested video transmission from Glass to a remote audience during surgery [6]. Likewise, some of the first scientific reports on Glass in medical education [7], documentation in forensic medicine [8], videoconferencing and information querying [9] have recently been published. However, there is a potential array of clinical use-case scenarios that have yet to be investigated.

Since it seems to be impossible to exhaustively list all specific use cases, we describe process settings where Glass could improve efficiency and effectiveness:

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Surgeons or interventionalists rely on information from various sources (e.g. patients' vital parameters, medical images, patient records, etc.). Due to the fact that almost all data is already in a digital form, it can be easily distributed to various devices. Therefore, if there are at least two, eventually dislocated, information sources needed to perform a task, wearable devices can bridge local gaps and collect data where it is needed. This is especially true in a clinical setting where users frequently need to monitor data (e.g. vital parameters) while performing their core tasks (e.g. interventions or surgeries).

Furthermore, Glass can be suitable for information sharing between separated medical staff. This may range from local information sharing (different patient perspectives – e.g. small size of incision) to national and international information sharing (e.g. remote consultations).

Our research was guided by the following questions:

- Where and how might Glass increase efficiency and effectiveness?
- How can data be protected when using Glass?
- What are the possible benefits and drawbacks of using Glass in clinical situations?

Glass appears to be a suitable platform for user-centered medical information services with rich potential for further development.

The publicly available programming interfaces (Glass Development Kit and Mirror API) will likely be fertile ground for further development. Importantly, the Glass Development Kit (GDK) provides developments that allow Glass to work on local networks (rather than the Internet). This is especially important for data privacy, and enables the implementation of secure end-to-end data transfer without third-party access.

We suggest the potential uses of Glass include tele-mentoring and training. Of several possible clinical applications we opted to develop a Glass app and a server app to enable Glass to be used during percutaneous transluminal angioplasty (PTA), with feedback from the two interventionalists involved in three such cases.

2. Methods

As depicted in Fig. 1, we followed a three-step approach. During the first step, our team identified several potential areas of improvement by the use of near-eye display devices through systematic requirements engineering based on the SOPHIST-Approach [10]. The SOPHIST-Approach is a technique in software engineering, which offers tools to systematically collect requirements that have to be met by a technical system in order to satisfy end users (e.g. physician) needs.

For our second step, we developed the classification scheme described in Section 2.1 to identify technical and organizational commonalities and differences of use cases before implementation. Use cases are classified according to the scheme depicted in Table 1. This scheme, which is located at the center of Fig. 1, facilitates abstraction of the identified applications to see that use case stories can be clustered or even be the same from a technical perspective. In a third step, the abstracted use cases are mapped to technical solutions.

On the one hand, the abstraction step prevents from reinventing technical solutions for each new user story. On the other hand the abstraction scheme can also be used as a process innovation tool by mapping various property combinations of the scheme to possible new use cases.

One especially promising scenario was selected and a technical solution was implemented. After initial lab experiments, this application framework was tested during three real world interventions (angioplasties) and feedback was collected from the participating interventionalists who wore Glass during the procedure.

Similar to [9] we categorize the identified areas of improvements by the use of near-eye display devices into “Virtual Consultations” (bridging of spatial barriers), “Monitoring of real time patient data” (improvement of situational awareness, reduction of change of attention and focus), “Navigation and medical imaging” (reduction of change of attention and focus), “Viewpoint of surgeon for assistance” (improvement of assistance by projection of the viewpoint of surgeons to assistance e.g. in case of small size of incision) and “Teaching” (transmission of the point of view of an experienced expert to students, respectively from an inexperienced student to an expert for remote consultation). In order to facilitate implementation by identifying technical and organizational differences and similarities we propose the categorization scheme described in the following section.

2.1. Scenario categorization

Based on process analysis and interviews with medical experts we identified requirements for human-centered information services and formulated use cases. We categorized them according to:

- **Number of users**: The number of users per scenario can either be single or multiple.
- **Data dynamics**: Data transferred to the near-eye display device can be either *static* (e.g. electronic health records) or *dynamic* (e.g. patient vital signs).
- **Collaboration**: Determines whether users will or will not collaborate based on the Glass service.
- **Direction of information flow**: The direction of the information flow can either be *unidirectional* or *bidirectional.* The unidirectional flow can further be refined into information transferred into the near-eye display device (e.g. patient vital signs) and information recorded by the near-eye display device and transferred outbound (in case of a near-eye display device with recording functionality).
- **Mode of operation**: The mode of operation can be classified as *passive*, or *active.* A passive mode of operation means that the end user does not actively control the near-eye display device during the scenario. Conversely, active mode of operation represents scenarios where users actively control the device (e.g. tapping on an integrated touch pad or using voice commands).
- **Frequency of use**: This criterion categorizes the frequency of the selected scenario in the setting investigated. We introduced the following three levels of frequency “High - daily use”, “Medium -weekly use” and “Low – monthly use”
- **Network coverage**: Based on the scenario, the network needed for data transmission can be local, regional, national, or international.

2.2. Scenario analysis

Detailed process analysis of various interventions revealed that a high degree of multitasking by interventionalists is required. This frequently means having to rely on multiple monitors and displays arranged around the operating theater while concentrating on the fields of operation (see Fig. 2). Such an arrangement requires a change of attention and focus potentially resulting in loss of efficiency.

We note that there is room for process improvement by using near-eye display devices to display relevant data directly into the