Qualitative Study of Surgeons Using a Wearable Personal Assistant in Surgeries and Ward Rounds

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Abstract. In this paper, we report on the utility of a wearable personal assistant (WPA) for orthopedic surgeons in hospitals. A prototype of the WPA was developed on the Google Glass platform for supporting surgeons in three different scenarios: (1) touch-less interaction with medical images in surgery room, (2) tele-presence colleague consultation during surgeries, and (3) mobile access to the Electronic Patient Records (EPR) during ward rounds. We evaluated the system in a simulation facility of a hospital with two real orthopedic surgeons. The results of our study showed that while the WPA can be a viable solution for touch-less interaction with medical images and remote collaborations during surgeries, using the WPA in the ward rounds can have a negative impact on social interaction between surgeons and patients.

Keywords: Wearable Personal Assistant · Google Glass · Hospital work

1 Introduction

Mobility is one of the main characteristics of work in hospitals. Due to the spatial distribution of departments, wards, and offices in clinical settings, clinicians need to move between different departments all the time. Aside from the considerable time that clinicians waste on moving in hospitals, having access to the right information in different situations is a big challenge. The majority of previous work on providing remote access to the patient information have used mobile devices (e.g. PDAs and smartphones). However, most mobile devices do not support interaction on the move, which means the users need to stop, pick up their device, and direct their attention away from the task at hand [1]. This way of interaction often requires the user's full attention and occupies at least one hand which most of the time interferes with the task at hand. Furthermore, interaction with the dominant touchscreen-based mobile devices does not comply with sterility restrictions in hospitals. Emerging new generation of eyewear computers e.g. Google Glass that provide various hands-free input modalities (e.g. head motion and voice commands), raises the question as to whether this new platform can address some of the challenges of interaction on the move.

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What are the potential advantages and limitations of using such devices in hospitals? To answer these questions, we implemented and evaluated a wearable personal assistant (WPA) for orthopedic surgeons based on a previous study on design of wearable personal assistants for surgeons [2]. Our WPA supports three specific tasks throughout a workday of surgeons: (1) touch-less interaction with medical images, (2) tele-presence during surgeries, and (3) mobile access to the Electronic Patient Records (EPR) during ward rounds.

2 Related Work

2.1 Early Wearable Assistants for Clinicians

The first generation of wearable computers for hospital work domain [3–7] comprised a head mounted display (HMD), a microphone and earphone for vocal interaction, a compact processing unit connected to a wireless network, and other peripherals such as wrist-mounted keyboards, trackball mice, and etc. RNPSS [3] was one of the first wearable systems for clinicians. The main goal of this system was to decrease the medical errors of nurses. A similar project [6] was done to support nurses in home care tasks. Supporting physicians in ward rounds was another application for the early wearable assistants [4]. The ward round system supported hand gesture interaction using inertial sensors [4] and conductive textile sensor [8]. These initial prototypes of wearable assistant for clinicians increased hopes for using wearable computers in practice, but due to the technical, social, and usability challenges [9] those system never took off.

2.2 Using Google Glass in Healthcare

In [10], an expert surgeon provided guidance to a local surgeon over distance. The guidance was provided through vocal communication and the image of the remote surgeon's hand was superimposed on the live view of the surgical site on the Google Glass HMD. This study showed some problems with battery life, audio and image quality, and difference between camera view and the surgeon view. In another study [11], Google Glass was used to retrieve similar medical cases by sending a picture and relevant keywords to a remote server. In this paper, similar technical issues were reported such as limited battery life, unstable WIFI connection, lack of auto-focus functionality, which decreases the quality of the pictures. Muensterer et al. [12] showed the utility of the Google Glass for hands-free photo and video recordings, hands-free calls, looking up billing codes, and searching for unfamiliar medical terms in a hospital. The feasibility of using Google Glass for monitoring patient's vital signs in the surgeon's eye was investigated by Vorraber et al. [13]. Their study showed that using Google Glass decreases head and neck movements of the surgeon and increases the surgeon's focus on the operation. They reported over-heating problems of the Google Glass in addition to the other technical issues. While previous work has focused on the technical feasibility of using Google Glass in healthcare scenarios, our focus here is on human-computer interaction challenges emerging from using the device as a wearable assistant in hospitals.

In the work presented in this paper we investigate the ecological validity of the WPA design explained in more detail elsewhere [2] by asking real orthopedic surgeons use the WPA in a clinical simulation.

3 Method

Since deploying the WPA in a real clinical setting needs legal approval, we evaluated the WPA in a clinical simulation facility. Such simulations is common and have been proven efficient in the medical work domain [14]. Our simulation facility includes different hospital departments from patient wards to surgery rooms. We set up the facility for the above-mentioned three scenarios. The touch-less interaction and tele-presence scenarios were played out in the surgery room (see Fig. 1b), and for the mobile access to the EPR scenario we set up a patient room with two beds (see Fig. 1a).

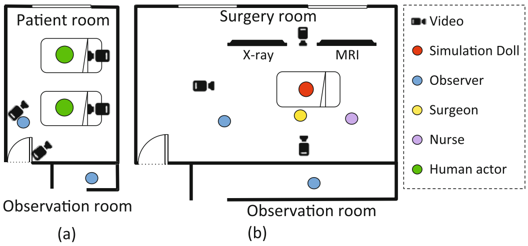


Fig. 1. (a) The simulation setup for the ward round scenario. The room is equipped with hidden cameras, microphones, and an observation room behind a one-way mirror. (b) The simulation surgery room for touch-less interaction and tele-presence scenarios is equipped with surgical equipments, a simulation doll connected to a monitor displaying simulated vital signs, and two large screens for displaying X-rays and Magnetic Resonance Images (MRIs).

3.1 Participants

During a full day simulation, two orthopedic surgeons, a senior nurse, and two human actors (to play the role of patients) participated in the study. Since surgeons are extremely busy and hard to recruit for such studies we could manage to find only two surgeons. This is a big limitation for finding statistical significance; therefore, we only rely on qualitative findings from interviews and observations. The entire simulation was recorded using video cameras, note taking, photographing, and observations behind a one-way mirror. After welcoming the participants, a brief introduction was delivered on the purpose of the study and the scenarios. Both surgeons performed all three scenarios. Before starting each scenario, the surgeons were briefly trained on how to use the WPA.

Each training session took about 30 min. After each scenario, the surgeons were asked to complete a structured questionnaire polling their experiences completing the task and using the system. The result of questionnaires is represented in Fig. 3. Immediately after the questionnaire the surgeons were interviewed to get deeper insights into their experience of using the WPA.

3.2 Scenario-Based Evaluation

We took a scenario-based approach in evaluation of the WPA. The scenarios were defined based on a previous study [2]. Scenarios included: (1) Touch-less interaction, (2) Tele-presence, and (3) Mobile access to the EPR in ward rounds. These three scenarios are part of a bigger scenario which starts with a patient getting an orthopedic surgery. Before the surgery, the surgeon needs to review the medical images of the patient. The WPA helps the surgeon find relevant medical images and adjust the view through touch-less modalities. During the surgery, the surgeon needs another experienced surgeon's opinion about the surgery. The WPA helps the local surgeon to have a tele-presence session with the remote colleague. After surgery, the patient is moved to the ward, and the surgeon visits the patient in the ward. The WPA enables the surgeon to see the patient electronic records on the go and review the new medical images after the surgery.

3.3 Preparing Data for the Study

Since all three scenarios are related to each other, for this study we needed real medical cases. We selected two cases with the help of our medical partner. We anonymized the data and assigned unreal names to the selected cases. Two human actors from university staff played the role of the patients during the ward round scenario. We also used real pictures of the surgical site taken during real surgeries. The pictures were printed and attached to the simulation doll to create a more realistic view (see Fig. 2-a).

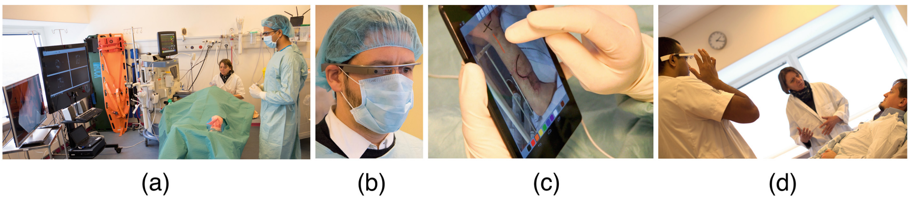


Fig. 2. (a) A surgeon uses the WPA for touch-less interaction with X-rays and MRIs. (b) The local surgeon sees the visual guidance on the HMD in real-time. (c) A remote surgeon uses a tablet device to provide guidance to the local surgeon. (d) A surgeon uses the WPA to browse EPR and X-rays in the ward round scenario.

4 Scenario 1: Touchless Interaction

In the surgery room, the surgical team including a surgeon and a nurse, are about to start the surgery. Before starting the surgery, the surgeon looks at X-rays and MRIs. But his/her hands are sterile and s/he cannot touch the mouse or keyboard. Therefore, the surgeon uses the WPA for browsing X-rays and MRIs on two different screens in the operation room through voice commands and head movements. The surgeon might need to zoom in, rotate, or navigate through the medical images until s/he finds a good view. The surgeon can also take a snapshot of the screens and see the content on the HMD.

4.1 Apparatus

We used Google Glass to implement the WPA since Google Glass provides at least two touch-less input modalities: voice commands and head movements. Moreover, the unobtrusive form factor of the Google Glass and covering small part of the users field of view makes the Google Glass the best available option for applications where having a good view over the real-world is crucial. We developed a simple image browser for displaying the X-rays in the surgery room. To visualize MRIs and X-ray scans, we modified Invesalius software that is an open-source medical imaging system[1].

All three systems were connected to a dedicated local WIFI network. We used UDP protocol for communication between Google Glass and other two medical systems. The WPA app on the Glass accepts both voice commands and head movements for interaction. Voice modality is used for discrete commands such as activating/deactivating the interaction, switching between X-rays, zooming in/out X-rays, changing the views in MRIs between (sagittal, coronal, and axial). While head motion is used for continuous commands such as adjusting the position of the X-rays on the screen. In the latter case, we used the user's head similar to a mouse where the vertical and horizontal head movements are translated into the vertical and horizontal movements of the pointer displayed on the HMD. We defined some command areas in the GUI of the Google Glass. By moving and keeping the pointer in each area, the WPA sends an appropriate command to the X-ray and MRI systems. As soon as the pointer exits from the selected area the WPA stops sending commands. Table 1 shows the modalities used for sending commands to the WPA.

4.2 Procedure

After briefing the participants and setting up the surgery room, the surgeons started the scenario one after another. First the nurse gave a brief explanation about the patient to the surgeon. Then the surgeon activated the stationary X-ray system through the WPA to find an X-ray and adjust the scale and position of it on the large display. To find a good view the surgeon used either voice

[1] http://svn.softwarepublico.gov.br/trac/invesalius/.

Table 1. Input modalities for each module of the WPA

System module	Commands to the WPA	Voice	Head	Touch
Touchless interaction	Wake up the Glass		×	
	(De)activate the X-ray/MRI system	×		
	Switching X-rays (next/previous)	×		
	Positioning X-rays on the screen		×	
	Changing MRI views	×		
	Change the depth of the MRI views		×	
	Take snapshot of X-rays/MRI views	×		
Tele-precense	Wake up the Glass		×	
	(De)activate the tele-precense system	×		
	Take a picture	×		
	Select a picture for sharing	×		
	Call a clinician	×		
	End call	×		
EPR	Wake up the Glass		×	×
	(De)activate the EPR system	×		×
	Select a patient record	×		×
	Switch X-rays	×		×
	Zoom in/out X-rays	×		×
	Rotate X-rays	×		×
	Navigate through X-rays		×	
	Browse EPR pages	×		×

commands or head movements as shown in Table 1. After finding the appropriate view, the surgeon took a snapshot of the stationary X-ray which made it come up on the HMD. This snapshot helps the surgeon to examine the X-ray image during the surgery without having to change the head orientation towards the large display. Each surgeon repeated the scenario for both patients. Since the second patient had also some MRIs, in the second surgery, the surgeons used the WPA for interaction with both X-rays and MRI systems. To interact with the MRI system, the surgeon needed to activate three different views (sagittal, coronal, axial) through voice commands and adjust an appropriate depth view.

4.3 Results

Interview: We asked surgeons about the pros and cons of the WPA for touchless interaction compared to the current indirect interaction (asking a nurse to control a computer mouse as proxies for surgeons). Participant 1 (P1) indicated the higher speed of interaction using the WPA; however, he believes that it might take more time for older surgeons to learn how to use the WPA. P2 thinks the direct interaction through the WPA can be a big advantage and saves time of surgeons in the surgery room because sometimes it is very hard to explain to a nurse the view that the surgeon is looking for. However, interaction with X-rays by head movements is not easy since the user needs to look through the HMD to see the pointer and at the same time look at the X-rays or MRIs on the large screens which demands frequently switching between the HMD and the large screens.

We also asked whether they prefer voice commands or head movements for interaction with X-rays and MRIs. P1 thinks the voice commands are more convenient for interaction with X-rays where the user usually needs to provide a few commands while in the MRI case the head movements can be more beneficial since finding the right depth view among a lot of slices can be frustrating by voice commands. P2 prefers voice commands since interaction through head movements was challenging for him due to the need for switching frequently between the HMD and the large screens.

The last question was about the snapshot function. Both P1 and P2 indicated that the snapshot functionality can be extremely useful when the surgeon needs a reference X-ray or MRI to monitor the state of the surgical site during the surgery. In such cases, the surgeon needs to frequently turn his/her head towards the screen. To have a snapshot of such reference images in the HMD, saves surgeons' time and energy for the surgery.

Observations: Both surgeons quickly learned how to use the voice commands for interaction through the WPA; however, P1 felt more comfortable with head-based interaction compared to P2. When P2 wanted to adjust the position of the X-rays in the screen by head movements, he lost the control of the system because he had problems with looking at both the HMD (to control the pointer) and the large screen (to see the X-rays) at the same time. The same problem happened when P2 wanted to adjust the MRI depth view.

5 Scenario 2: Tele-Presence

After adjusting the medical images on the screen (in the previous scenario) during the surgery, the surgeon encounters a complex situation and needs help from an expert colleague. The surgeon uses the WPA to start a tele-presence session with the remote colleague. The local surgeon takes a picture of the surgical site and calls the remote surgeon using the Glass. The remote surgeon answers the call. Then the local surgeon explains the situation and shares the taken picture with the remote surgeon. The remote surgeon provides some voice guidance while at the same time marking the shared photo on his tablet (Fig. 2c). The local surgeon sees the content provided by the remote surgeon on the Glass and also hears the voice of the remote surgeon in real-time (Fig. 2b) in real-time.

5.1 Apparatus

We developed a tele-presence app on the Google Glass for the local surgeon while for the remote surgeon, we developed an Android application on an Asus

Nexus 7 tablet. The audio communication is done over WIFI connection using UDP protocol. Due to the limitations in processing resources of the Google Glass and to avoid registration challenges in an augmented reality user interface, the Glass application shares a still picture (instead of video) of the local side, and the remote person is able to draw sketches on top of the shared image using the Android application on the tablet. The sketches are superimposed over the shared image in real-time on the Google Glass HMD of the local user.

5.2 Procedure

In the tele-presence simulation, we ran the scenario twice, and during each time one of the surgeons played the role of a remote expert and the other surgeon played the role a local surgeon. In the second run, the surgeons swapped their role and the surgery case was also changed from patient 1 to the patient 2. Before starting each run, we attached the printed image of the surgical site on the simulation doll. The remote surgeon sat on a chair in the hallway outside of the surgery room. After activating the Google Glass by head nudge gesture, the local surgeon opens the tele-presence application by voice command and takes a picture of the surgical site. Then the local surgeon calls the remote colleague by saying his/her name from a list on the HMD. The remote surgeon receives and accepts the call. As soon as the call is accepted the audio communication is possible and the taken picture is displayed on both sides. The local surgeon explains the situation and asks for the remote surgeon's opinion. The remote surgeon provides vocal and visual guidance by marking the shared image of the surgical site using different colors on his tablet device, markings that show up immediately in the Google Glass display carried by the local surgeon.

5.3 Results

Interview: We asked surgeons what other content they would like to share in a tele-presence session. P1 believes sharing still images of the surgical site (like our implementation) is very useful for orthopedic surgeries while live videos can be useful in emergency cases. Also sharing medical images such as X-rays or MRIs can be valuable in cases where a junior surgeon needs an approval from a senior surgeon. Currently the senior surgeon needs to come personally to the surgery room and have a look at the X-rays or the junior surgeon sends the X-ray using a smartphone. P2 thinks the quality of the image on the HMD is not good enough for complex surgeries with a lot of soft tissues. He suggested to add a zoom-in functionality to overcome the limited resolution of the HMD.

Observations: The communication between the two surgeons was smooth. There was about half a second delay in the audio communication due to the WIFI-based communication. But the surgeons got used to it after a while. Also during the tele-presence scenario, when the local surgeon was talking to the remote surgeon, Google Glass detected the "Ok Glass" command by mistake and the surgeon needed to deactivate the voice command and continue the session.

6 Scenario 3: Mobile Access to Electronic Patient Records

It is one day after the surgeries. Patients are lying down in the bed in the ward. The surgeons should visit two patients who got surgery. The surgeons use the WPA to review the new X-rays and the latest state of the patients while walking to the ward together with a nurse. The surgeon searches for the patient records on the Glass by saying the patients name. After finding the patient records, the surgeon reads the updated EPR and looks at the recent X-rays and MRIs on the Glass. The surgeon zooms in/out, rotate, and navigate through the medical images. The nurse reports the latest state of the patient (last blood test, etc.) to the surgeon. The nurse answers the questions that the surgeon might ask during the ward round. The surgeon visits the patients and asks some questions about their pain, etc. Also the surgeon might need to use the EPR system for answering patients' questions. After visiting the patients, the surgeon prescribes the next treatments and the nurse writes down the prescriptions.

6.1 Apparatus

For this scenario, we only needed an EPR app on the Google Glass. Since in the ward round, the clinicians' hands do not necessarily need to be sterilized, the EPR app supports also touch-based interaction on the Google Glass side touchpad. Table 1 shows the ways surgeons can interact with the EPR app. We used different touch-gestures for interaction with text pages and medical images: swipe front/back for browsing EPR and X-rays, short tap for zoom in, long tap for zoom out, swipe up for 90 ° rotation, and swipe up to exit from an active card to the previous menu. Since it was not possible to connect the Google Glass to the EPR in the hospital, the patients data was hard-coded into the EPR app.

6.2 Procedure

In the ward round simulation, each surgeon performed the ward round scenario once where both patients (human actors) lying in the patient bed (Fig. 1-a) were visited. A nurse accompanied the surgeon during the ward round and provided necessary information. The surgeons used the WPA to see the recent EPR and X-rays while talking to the patients (see Fig. 2-d). They tried both voice commands and touch gestures to interact with the WPA. The patients also asked some questions about the result of the surgery.

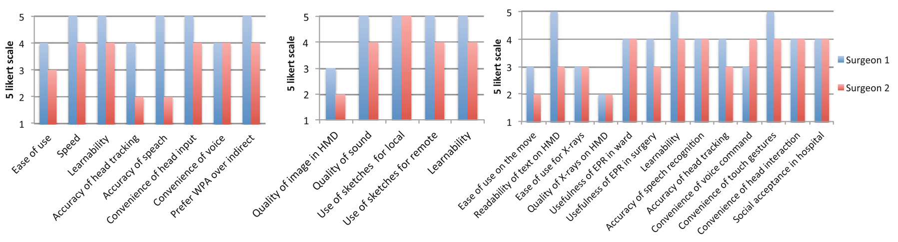
6.3 Results

Interview: The surgeons were asked about the pros and cons of the EPR module during ward rounds. P1 mentioned that the most obvious advantage of using the EPR on the Glass is to reduce unnecessary moving between a stationary computer and the ward to check the EPR. However, P2 thinks the small screen in Google Glass makes it hard for the surgeon to read the EPR texts, while a stationary computer is more convenient for such intensive readings. P1 also mentioned that getting an overview of the EPR is much faster using a desktop computer since in Glass the text is distributed over several pages.

The other question was about the content that surgeons might need to have access to during a ward round in addition to the EPR and medical images. P2 mentioned that the main information the doctors need during a ward round is lab results that can also be provided on the Glass. However, due to the small size of the HMD in Google Glass, the lab results should be visualized in a way that the interesting results (important abnormal values) are highlighted, and the surgeon can get what s/he wants at a glance. P2 indicated that aside from the medical data, patients usually ask a lot of practical questions about e.g. when they can leave the hospital, when they have their next appointment, etc. The WPA should also provide such practical information to the surgeon.

We also asked about the modality they prefer to use during ward rounds. P1 mentioned that he prefers touch gestures since the voice commands interfere with communication with the patient. P2 said "*I also prefer touch gestures because the head movements look bizarre!*". All participants (two surgeons, a nurse, and two patients) were asked about the social acceptance of the Google Glass. P2 said: "*Some people might think wearing such a [smart] glasses is arrogant since you are not present with the patient*". The nurse mentioned that sometimes the surgeon was looking at the HMD but she thought the surgeon is looking at her. Moreover, the patients mentioned that they did not feel good when the surgeon was trying to interact with the Google Glass instead of talking to them.

Observations: During the ward round, P1 spent more time for interaction with the WPA compared to P2 and sometimes there was a long silence until the surgeon read the EPR on the Google Glass. The reason was that P2 was familiar with the medical cases used in the simulation while both cases were new for P1.



(a) Usability of touch-less interaction (b) Usability of tele-presence (c) Usability of EPR

Fig. 3. (a) Usability of the touch-less interaction module of the WPA, (b) usability of the tele-presence module of the WPA, and (c) usability of the EPR module of the WPA.

7 Discussion and Conclusions

Our study indicates that using the WPA for touch-less interaction with medical images can save surgeons time and energy for the surgery. Moreover, by using the WPA for touch-less interaction, there is no need for a dedicated nurse to control the mouse for surgeons. However, there are some limitations in both voice commands and head movements for touch-less interaction. Using voice commands is a relatively reliable modality but due to the slow speed of the discrete voice commands, it is not an appropriate modality for providing a lot of commands within a short time. In contrast to the voice commands, the head movements can be useful for continuous interactions; however, due to the perceptual overlap between seeing the large screens and the pointer on the HMD, it is not easy to use the head movements as a mouse to control the pointer on the HMD. The lowest scores in Fig. 3-a are related to the accuracy of head tracking specially by P2. This reveals the challenge of using head movements for touch-less interaction.

Apart from the low quality of the image on the HMD indicated in both questionnaire (Fig. 3-b) and the complementary interview, the WPA was successfully used in the tele-presence scenario. As both surgeons mentioned, the tele-presence scenario was the best application for the WPA. However, in this scenario we observed the problem of overlapping between human to human conversation and voice commands to the system. This indicates a need for more touch-less input modalities (e.g. gaze) to avoid overlap between the input modality (voice commands) and surgeons' conversation. The most challenging scenario was the ward round which revealed the social problems of using Google Glass in parallel with human to human interactions. Apart from the social problems, the small HMD of the Glass turned out to be a limitation for intensive text readings which is in line with the concept of microinteractions [15] where interacting with the device should not exceed 4 s. To achieve such fast interactions, the WPA needs to prepare the information for the surgeons in a way that the surgeon can get what s/he needs at a glance.

The three scenarios in this paper are representatives of three types of interaction. (1) The touch-less interaction scenario defines the WPA as an *interface between the user and other computers*. In this type of scenarios, the human agent interacts with two different computers in parallel. (2) In the tele-presence scenario, the WPA is defined as an *interface between two human agents* which means the user interacts with another human agent through the WPA and there is no parallel interaction. (3) In the ward round scenario, the user interacts with another human agent and with the WPA *in parallel*. If we look at the results of the questionnaires and interviews, we can conclude that the WPA got the best scores in the tele-presence scenario where there was no parallel interaction, and the user interacts sequentially with the WPA and the other human agent. In the touch-less interaction scenario, the usability of the WPA is evaluated as average. In this scenario, the user interacts with two computers in parallel: the WPA and X-ray/MRI systems. The most challenging scenario is the ward round where the user needs to interact in parallel with the WPA and a human agent.

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