HyPR Device: Mobile Support for Hybrid Patient Records

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ABSTRACT
The patient record is one of the central artifacts in medical work that is used to organize, communicate and coordinate important information related to patient care. In many hospitals a double record consisting of an electronic and paper part is maintained. This practice introduces a number of configuration problems related to finding, using and aligning the paper and electronic patient record. In this paper, we describe the exploration into the Hybrid Patient Record (HyPR) concept. Based on design requirements derived from a field study, followed by a design study using a technology probe, we introduce the *HyPR Device*, a device that merges the paper and electronic patient record into one system. We provide results from a clinical simulation with eight clinicians and discuss the functional, design and infrastructural requirements of such hybrid patient records. Our study suggests that the HyPR device decreases configuration work, supports mobility in clinical work and increases awareness on patient data.

Author Keywords
Hybrid Patient Record; Electronic Health Record; HyPR; EHR; Nomadic Work; Hospitals

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INTRODUCTION
The patient record is one of the most important artifacts in medical work in hospitals as it is used as a central legal document to organize patient data, communicate relevant information with other clinicians and departments, and coordinate complex patient treatment procedures. In recent years, the Electronic Health Record (EHR) has been introduced in an effort to provide a higher level of quality in healthcare through a more efficient, safer and unified workflow. EHRs have a number of important advantages over traditional paper records, including a higher degree of security, simpler workflows, standardized documentation and more accurate and widely available access to patient data [26].

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Figure 1. A Hybrid Patient Record (HyPR) device augments the paper patient record with color configuration and location tracking, while allowing clinicians to pair a tablet which shows the digital information associated with the paper record.

However, by attempting to replace paper records with an electronic counterpart, the affordances (such as handleability, manipulability and portability [15]) of paper-based interaction are removed. In many hospitals, the paper record is therefore still actively used as a central artifact for day to day work, despite the widespread deployment of EHR systems [25, 33]. These paper records are also frequently used for the storage of more informal documentation such as e.g., nursing notes or other working records, which again adds to their importance. Prior studies have even shown that paper helped some clinicians to be more efficient in their work [21]. Consequently, a typical setup in many hospitals is that the EHR system does not replace the paper-based record, but instead a *double record* consisting of both an electronic and paper part is maintained.

This double medical record introduces a number of configuration problems related to finding, using, and managing both the paper and electronic representation of the patient record. First, the usage of both electronic and paper records causes synchronization problems between both representations [27], forcing clinicians to deal with the paper and digital information simultaneous. Since digital information is often only available through desktop computers, it requires clinicians to sit at a desk when interacting with patient data. Second, since many hospitals require the use of a unique paper record, it is often transferred between different departments and wards as patients and clinicians move throughout the hospital. This causes paper records to be physically misplaced in the ward or even lost between departments resulting in clinical staff tracking down the record.

To mitigate these configuration problems, we introduce the Hybrid Patient Record (HyPR) device as shown in Figure 1.

The paper-based medical record can be augmented with the HyPR device, which supports notifications (color and sound), location tracking, and provides an easy way to link to the electronic patient record. This paper reports on the user-centered design and implementation of the HyPR device and presents four contributions: (i) we propose three design principles for hybrid patient records that are derived from a field study; (ii) we report on a design study, in which ten clinicians participated in a design walkthrough of a technology probe; (iii) we describe the design and technical implementation of a HyPR device and supporting infrastructure; and (iv) we analyze the preliminary results of a clinical simulation of the HyPR device.

RELATED WORK

A large body of research has explored the connection or linking of paper to digital data. One of the earliest approaches is DigitalDesk [29], an interactive desk that adds electronic features to physical paper and physical attributes to digital information using a top mounted camera and projector. Inspired by this work, the Paperlink [2] system attempted to scale this approach down by using a portable video pen. Based on this idea of a digitized pen (and commercial versions such as Anoto), other approaches such as the *Paper Augmented Digital Documents* (PADDs) [7], Paperproof [28] and PapierCraft [13] provide support for digital annotation of paper documents using pen gestures.

To increase support for mobility, several approaches proposed to use PDAs or phones as mediator between paper and digital information. Circa [9] proposes the "paper PDA" concept in which they use the *StickerLink* approach to link paper and digital information. A-book [16] overlays physical notes with a PDA and Pacer [14] uses a phone to link paper documents to digital versions based on visual features. Prism [24], S-Notebook [19], and ButterflyNet [31] further explored the design and impact of hybrid approaches in which paper notes and digital counterparts were linked together. Finally, a number of approaches explored the creation of broad hybrid workspaces, that included support for paper documents. Magictouch [18] is an early approach that uses RFID technology to detect the location of physical documents in a defined space. The Designers' Outpost [11] recognizes paper documents using a rear camera. IdeaVis [6] provides a hybrid brainstorm space by augmenting paper documents with interactive zones. Finally, Penbook [30] is a hybrid approach providing a touch screen together with a built-in projector integrated with a wireless pen to support handwriting for prescriptions or patient registration in hospitals.

A number of approaches have explored different ways to augment or enhance the medical record. Rodriguez et al. [20] demonstrated a location-aware information system for medical work, which estimates the clinicians' location to find available patient data and display it on a mobile device. Similarly, the MobileWard system [23] provides a context-aware mobile patient record system for hospital wards aimed at supporting autonomous adoption to the changing tasks or location of the nurses. A more radical approach to context-aware computing in hospitals is presented in the Activity-Based Computing project [3], which proposes a new paradigm for context-aware information access and collaboration in patient wards, using *activity* as a central construct. The augmented paper chart [32] augments a single paper chart with an Anoto interface, thus supporting seamless integration of traditional paper-based notes and digital storage. However, despite the fact that several studies point to the importance of the physical paper record, it has received remarkable little attention in the development of these new pervasive interactive patient record and information systems.

In general, prior work has primarily focused on ad hoc tracking and local linking of single paper documents to their electronic representation. But as pointed out by many studies of hospital work, medical workflow is highly nomadic and collaborative [3, 25]. The nomadic nature of clinical work puts forward a set of fundamental challenges in terms of locating and tracking artifacts, while the collaborative nature implies that support for exchanging and sharing artifacts, material, resources, and devices should be part of the system design. Compared to prior work, the core contribution of this paper is the physical/digital integration of the entire medical record in the nomadic and collaborative work setting of a hospital, thus complementing per-document approaches. The novelty of the HyPR device is thus its unique attempt to connect and align *the entire medical record* using a mediating sensor platform.

FIELD STUDY

To understand in depth how paper and electronic patient records are used, we conducted a field study. Over a period of two months, we studied five different medical departments, covering two patient bed wards, two surgical departments, and the emergency department. We performed task-centric, artifact-centric, and place-centric observations, contextual inquiries through shadowing of nurses, and post-hoc interviews.

The medical record

The hospital in this study uses one unique paper-based medical record for each admitted patient. It is a legal requirement that this patient record is present at the ward or department that is treating the patient. The paper record is made of a plastic binder with explicit color-coded sections for patient data, continuation (treatment history), nursing notes, various schemes and forms, observations, test results (e.g., blood tests and radiology examinations), and correspondence with other medical professionals. On the front, the binder has a label with the patient's name and ID written both in text as well as encoded in a bar code. On average the patient record is between 2 and 3 cm thick.

In parallel to the paper record, the hospital uses a number of specialized health information systems, such as radiology, medication, patient administration, and blood bank systems. Access to these systems have been collated in a portal, which is referred to as the electronic medical record. The paper and electronic medical records are used simultaneously in patient treatment and are equally important for medical work. Most information is duplicated in both records, whereas other information only exists in one or the other. This creates significant synchronization problems between the two versions of the records, which again leads to extraordinary work in manual updating, verification, and cross-referencing. For example, a lot of work is put into printing from the electronic medical record and storing print-outs in the paper records. This leads to significant problems of updating and replacing the printed documents in the paper record, when information changes in one of the electronic systems.

The different health information systems are primarily used to request or create new medical information, such as ordering blood tests at the hospital lab. The physical medical record, on the other hand, is primarily used to archive patient information. Because lab results e.g., need to be put into the paper-based record, the lab system is configured in such a way that when a lab result is ready, it is sent directly to the requesting ward's printer. In this way, the test results are physically presented and the printer becomes a coordinative artifact that signals when test results are ready. At a patient ward, there are typically up to 25 records of active patients. But since records from dismissed patients are stored at the ward, hundreds of archived records are at the department. Finding the right paper record is challenging as there is no visual differentiation between records; they are all stacked upon each other and scattered all over the ward in the nursing station, the secretary offices, and in the archiving room.

Patient Record in Nomadic Work

Medical work in hospitals is inherently nomadic [4], which implies that clinicians and the tools they use (including the patient record) move around inside wards, departments, and the entire hospital. The paper records are mostly used in offices, nursing stations, doctors' offices, and at the bedside of the patient. As mentioned earlier, it is a legal requirement that the record is present during medical treatment, which implies that the record always 'travels with the patient'. For example, when patients are send to other wards (e.g., for x-ray or surgery), the record is mounted in a special container on the side of the patient bed and travels with the patient to the receiving department. Moving the record around inside the hospital again causes it to get lost or misplaced both inside the ward and in other departments.

HYBRID PATIENT RECORD CONCEPT

Prior research on medical work (e.g., [5, 17]) and our field study have identified a range of challenges associated with handling medical records. At its core, these challenges are tied to clinicians' need to handle, align and coordinate physical and digital information simultaneously. One way of approaching this challenge is to digitize all information in medical work – a strategy that is being pursued in the creation of integrated electronic medical records (EMR) and hospital information systems (HIS). However, several studies (including [17, 25, 33]) show that despite the 'successfulness' of the deployment of EMRs, paper documentation, artifacts and records are still widely used in documentation as transitional artifact [5] or as redundant information source in medical work. As such, the findings from the medical domain back up findings from the office environment about the 'myth of the paperless office' [22]. Therefore, rather than designing for the 'paperless hospital', there is a need to design for the parallel management of both paper and electronic medical records, thereby creating a *hybrid* medical record. Inspired by our field study and prior work, we propose the following three principles for the design of patient records.

- **D1 Dual Use** – Because the paper and electronic version of the record are almost always used simultaneously, setting up and removing the connection between the paper record and a device representing the electronic record should be instantly and easy. Both representations should be usable separately, without any changes to their original purpose or use. Since the paper record is used to identify the patient case, the hybrid record should use this patient context to load and visualize the correct data. To facilitate the usage of the double record, it should be integrated with existing practices, devices and technology.
- **D2 Recognizability** – To support easy identification and recognition of a patient record (e.g., in a cluttered office space) the patient record should be able to relay and display various kinds of status and awareness information. Temporal visual and auditory cues (similar to the analogue affordance of e.g., sticky notes) should be supported to provide clinicians with an easy and fast configuration mechanism for self-reflection or coordination with other clinicians.
- **D3 Mobility** – The patient record should support the nomadic workflow in hospitals, meaning that both the electronic and paper representation of patient data should be available in a portable and traceable form factor. To support clinicians in finding and managing the location of the record, the supporting infrastructure should support location tracking and remote access to the state of the paper record. Additionally, the location should be used to ease information retrieval.

To address and support dual use, recognizability and mobility in patient records, we propose the concept of a *Hybrid Patient Record* (HyPR). Conceptually, a HyPR setup consists of three parts: (i) the traditional paper patient record as used in hospitals today, (ii) the electronic record accessed from a tablet or phone, and (iii) a mediating platform that augments the paper record with a number of configurable properties and connects the paper record to the digital record on the tablet. The central purpose of this concept is to integrate the electronic patient record into the existing physical and mobile workflow of clinicians. By explicitly attaching digital information and notification systems to the existing paper record, the HyPR presents clinicians with a patient record that encapsulates existing practices but augments it with digital capabilities. In summary, the HyPR device allows for ad hoc integration of paper-based and digital information, authorized and fast access to digital information, customization of the record using the sensing platform, and traceability by location tracking.

DESIGN STUDY

To explore the feasibility of the HyPR device concept and to get a better understanding of the design and clinical implications of hybrid devices, we conducted a design study involving a group of clinicians from two different hospitals. The goal of this study was to get feedback on the design of a technology probe and use this as input for the design and implementation of the device. The study had two parts. First we introduced the concept of hybrid patient records to the clinicians in order to open up a discussion and brainstorm on the design dimensions and implications of the HyPR devices. Second, based on the use of a concrete prototype, we asked for detailed input on the perceived usefulness of the HyPR device in clinical work and the usefulness of its different features.

Technology Probe

Because it is often hard for clinicians to envision how they could benefit from technology, we performed a design walk-through on a fully working prototype. The technology probe was designed as an augmented hard-cover box with room for both the digital and physical paper version (Figure 2). To bridge the size mismatch between modern tablets and the paper record, the enclosure provides a dock for the tablet (Figure 2 B) and a slot for the paper record (Figure 2 C). The slot on the side allows for easy access and pushes the record together so it does not fall out while moving. The tablet dock is specifically designed so clinicians can securely mount their device, while still being able to use it. When interacting with both the paper and digital patient data, clinicians can simply remove the paper record from the slot and browse the paper and tablet data at the same time. The device is activated by inserting a patient record in the slot and mounting a tablet to the dock (Figure 2 A). The color and sound of the device can be controlled by using the application on the tablet. The enclosure thus creates a temporal connection between the paper record and tablet.

Study Setup

In total 10 clinicians (all female, mean age = 42, σ = 5,37) from two different wards participated in two separate design sessions. The first session included three clinicians from a surgical ward that the original field study discussed earlier, while the second session included 7 clinicians from the psychiatric ward of a different hospital that was not part of the prior field study. Participants included two doctors, a psychologist, a clinical specialist, a medical secretary and five nurses. All participants were highly experienced in day to day medical work in patient wards and rated themselves as average computer users ($\tilde{x}$= 3; *iqr*= 0). The design sessions were done *in situ* at the hospital ward of the participants.

Method

The design study consisted of three phases. First, participants were introduced to the concept of a hybrid patient record through a demonstration of the functionality of the technology probe. The introduction used a number of *scenarios* that were designed based on the field study discussed earlier and validated by the head nurse from the ward. After the introduction, a semi-structured interview and discussion session was initiated to allow the clinicians to provide feedback on the scenarios and the design of the technology probe. The data from the sessions were collected using audio and video recordings, note taking and pictures. After the semi-structured interviews, participants completed a 5-point Likert scale questionnaire, which was used to discuss the design and functionality of the technology probe.

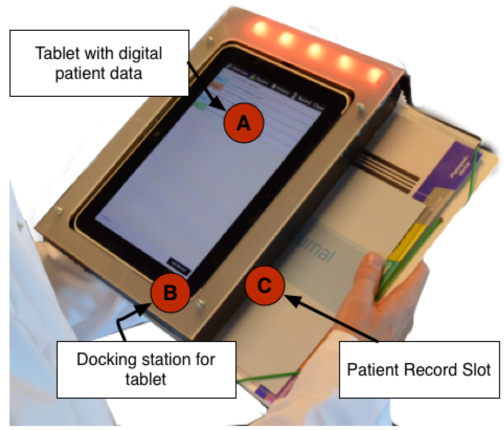


Figure 2. A fully working industrial prototype used as technology probe.

Results

In general, clinicians found that the HyPR device would be useful in clinical work. Although hospitals are trying to implement the vision of a 'paperless workflow', many clinicians realize that there are limitations to this vision, since much paper-based information does not exist in the digital world. This lack of one-to-one documentation between paper and digital information also greatly limits options to digitally augment individual records with e.g., Anoto technology. The basic functionality of being able to pair a paper-based and electronic record was considered as very useful. The contextualization of the visualized patient data, based on the paper record that was paired with the probe, was deemed as very important:

> – *"One of the key things of this device is the easiness of accessing patient data by getting rid of fixed computers and looking up patient data by simply placing the device on top of the paper record. That would save us a lot of time, and make the workflow a lot easier."* – *P3*

This instant and ad hoc pairing ability was especially valued for emergency cases in which patients are admitted with an acute problem:

> – *"Often when I have to treat acute patients – which I don't know in advance – this device would make it a lot easier to pair the paper record and the data in the electronic record. And I can do it anywhere and not only in front of my PC."* – *P8*

The ability to add color to the medical record was perceived as very useful. Clinicians mentioned that color is often used as a general coordination mechanism at the ward. For example, colored post-it notes are often used to indicate status information on patients. Tracking the device, thus locating the patient record was also considered very valuable. Clinicians responded that this would save them a lot of time and energy in finding the paper record, which can be stored anywhere, even *"under a pillow or in a drawer" (P1).* As explained by one clinician:

> – *"Not only tracking the record in the system is useful, but also providing visible and audible feedback which makes the record easier to find when you know what*

room it is in – just like the key finder gadgets where you can whistle and it then makes a sound". – P2

Although the working area and input/output bandwidth is significantly lower than desktop computers, all clinicians preferred to use a tablet over a PC for all day to day medical work. In general, the inclusion of a portable tablet into the system setup was considered an improvement for clinical workflow.

However, there was a general consensus that the size of the system – in this case the docking station – should be designed to fit into the pocket of a standard white coat. Several clinicians argued that the mediating device (i.e the docking station for the tablet) should be much more closely integrated with the physical folder of the paper record, arguing that the current HyPR device should somehow be merged into the paper record:

– "The idea of having a device that communicates with the paper journal, and using the journal to retrieve information on the device is super. However, I think the device as a separate object makes it laborious, and does not really fit the current work practice. If the clinician had his own tablet, which could interact with the patient record by simply placing it on top, would make it a lot more useful". – P5

Finally, clinicians in general argued that since the patient record follows the patient throughout the hospital, the device should be usable in different types of wards and clinical conditions, such as in operating rooms or the x-ray department.

Summary
Clinicians first of all argued that most of the functionality provided by the mediating enclosure of the technology probe, such as *location tracking* and *visual cues*, would also be useful once the patient record is archived and thus no longer active at the ward. These requirements extend the concept of the HyPR device from an ad hoc temporal mediator for active patient cases to a permanent augmentation and deep physical integration with the paper record. Second, clinicians stressed the importance of the HyPR device's ability to cope with the medical environment. The device should e.g., be strong enough to survive being dropped; interaction with the device should be possible while wearing latex gloves; and clinicians should be able to sterilize the device. Furthermore, the device should be constructed from food-safe plastic. Finally, clinicians generally argued that having the tablet physically docked to the record would not support their work practices very well. The general consensus was that the HyPR device should be usable with different size tablets and even phones, and that pairing the tablet to the device should be faster.

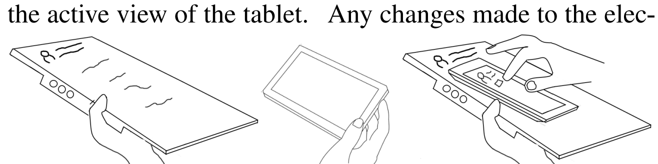
HYBRID PATIENT RECORD DEVICE
Based on the design principles and the results from the design study, we constructed the *Hybrid Patient Record* (HyPR) device as shown in Figure 1, 3, and 4. The HyPR device and its underlying infrastructure (Figure 7) are designed to integrate paper-based and digital patient information into the nomadic workflow of clinicians. The HyPR device supports *dual use* by allowing for ad hoc pairing between the paper and digital information. And, it provides clinicians with a mechanism to dynamically change some of the physical properties (color and sound) associated with the record. Finally, the device is equipped with a location tracker to allow clinicians to easily find the paper record. The HyPR device works within a larger infrastructure that supports location tracking, device management, and access to the electronic medical systems.

Figure 3. Two clinicians interacting with a number of HyPR devices scattered in the patient ward.

Design
The HyPR (Figure 3) consists of three distinct parts: (i) a traditional paper record, (ii) a tablet used to access the electronic record and (iii) a HyPR device. The HyPR device is a rectangular plastic plate with the same width and height as the paper record. Compared to the technology probe, it does not have any layers as all the electronics are integrated in the plate. The paper record is attached to the plastic plate using metal clips to create a permanent connection to the device. In contrast to the technology probe in which an active patient record is loaded into the device by inserting it into the slot, this version of the HyPR device is a permanent augmentation of the record. This means that the HyPR device becomes an inherent and inseparable part of the paper record.

Functionality
The HyPR device provides three features: (i) *pairing* of the tablet and the paper record using proximity sensing, (ii) *light and sound* system that can be used to augment the record or notify other clinicians, and (iii) an integrated *location tracking* unit that allows clinicians to locate the record.

Clinicians can interact with the HyPR by placing a tablet on top of the paper record and HyPR device. By doing so, they pair the tablet to the record, causing the underlying infrastructure to fetch the digital patient information and push this to the active view of the tablet. Any changes made to the elec-



tronic record are immediately propagated through the infrastructure and synchronized with any other paired devices. This process essentially eliminates extra configuration work during e.g., ward rounds or during emergency situations in which manually fetching information would be too time consuming or inappropriate. The device is thus used as a proxy that provides clinicians access to the activity of the patient. Although the initial pairing process is done by proximity, both the tablet

Figure 4. The color of the HyPR device can be configured to signal a wide range of things. For example, the colors can represent a specific nurse, patient status, or simply be used to highlight a patient record in an information dense environment.

and paper record can be used separately. When a user removes the tablet from the HyPR device, the data will remain coupled to the initial paper record until the user manually selects another patient, or pairs the tablet with another HyPR device. Furthermore, clinicians can also remotely connect to the record by selecting the patient case from the application. This allows multiple clinicians to work on the same patient case, while only having one physical journal. Only the paper record – not the tablet computer – is uniquely coupled to a HyPR device to ensure the infrastructure can correctly track and manage each record. (Supporting D1: Dual Use)

The HyPR device supports concurrent use and updates of both paper-based and digital information. For example, administration of medication in the medicine system can be done directly in the electronic medical record via the tablet computer. Similarly, ordering of lab tests can be done electronically by accessing the order-entry system. Simultaneously, paper-based information can be accessed from the paper-based record and ad hoc written notes can be added and stored temporarily in the physical folder. Moreover, electronic information – such as the lab results coming out of the printer – can be added in paper format to the folder. As such, the HyPR record supports blending paper-based and digital information in 'both directions'. (Supporting D1: Dual Use)

Once the device is paired, clinicians can change the physical properties of the HyPR record by changing its color scheme or identification sound. Figure 4 shows a number of different color configurations. These configurations can be used to relay status information. For example, a color can be associated with a specific nurse, thereby revealing who is the contact nurse for a specific patient. Or a color can represent a status change, by e.g., highlighting that there is a lab test result available for the patient. Moreover, sound and/or color can help locate records, which may be scattered all over the department. When the record is located in a cupboard or drawer, sound can be used to draw attention to the record. (Supporting D2: Recognizability)

The HyPR device supports nomadic medical work in several ways. First, in order to support location of medical records, the HyPR device is equipped with a location tag that broadcasts a unique value. This value is associated to a particular paper record, when the HyPR device registers the patient ID. Clinicians can look up the location of each patient record. Second, to minimize the burden of carrying both the augmented record and tablet, microsuction tape is attached to the front of the paper record to keep the tablet in place. Finally, the tracking capabilities of the HyPR device can be used to contextualize the patient's information. For example, if the HyPR device is taken to the patient's bed side (e.g., as part of a ward round), basic patient information and the latest entry in the record is shown, whereas the patient medicine treatment is shown if a nurse takes the HyPR record to the medicine room. (Supporting D3: Mobility)

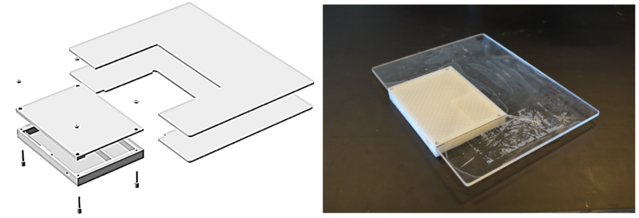


Figure 5. The physical parts of the HyPR device.

Technical Implementation

Figure 5 shows the design of the HyPR device. It consists of two different parts: (i) a rectangular plate of 2.5 mm food-safe transparent plastic, and (ii) an enclosure holding the electronics embedded into the side of the plate. Figure 6 shows the electronic architecture, which uses an Arduino ATmega168 chip 16 MHz crystal for basic processing; a RFID module with an antenna (125 kHz); a Texas Wifi CC 3000 module with antenna; an array of three high power RGB LEDs; a 2kHz range buzzer; an integrated rechargeable Volt battery pack with USB connector; a power switch; and a 35–45 kHz ultrasound tag with a dedicated 3V lithium battery.

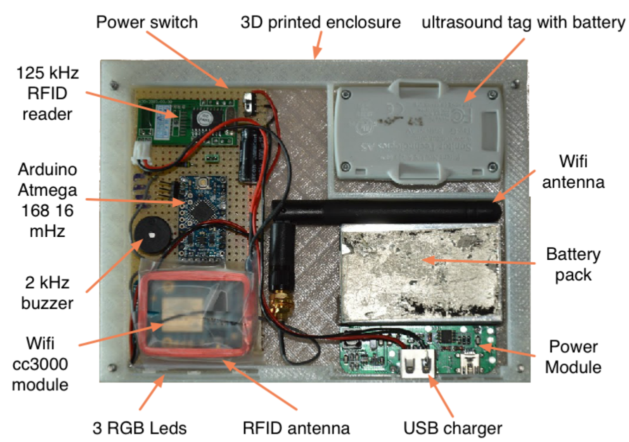


Figure 6. The electronics of the HyPR device.

To support two way communication between the tablet and the HyPR device, the firmware provides support for a custom protocol with a set of command messages. One set of messages allows the device to start a handshaking protocol when a tablet is paired and to send 'alive messages' that indicate that it is operating correctly. Other command messages allow the tablet to operate and configure the device's on-board buzzer and the RGB LED array based on e.g., user input or infrastructure changes. The RFID module continuously reads all nearby RFID tags and sends tag IDs to the Arduino board.

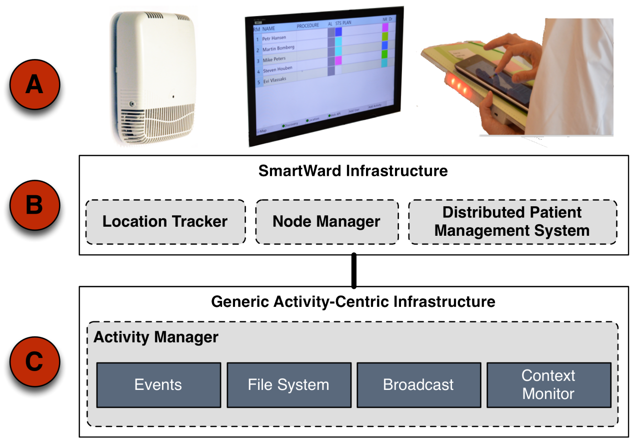


Figure 7. The *HyPR infrastructure* (B) is a distributed context-aware infrastructure designed to support multi-device location-aware collaborative workflows in patient wards. The infrastructure uses an ultrasound location tracker for location-aware services (A) and is built on top of a general purpose activity-centric infrastructure [10] (C).

When a new tag is detected, the device sends a message over Wifi to the infrastructure, which then pushes the data to the tablet. Similarly, any changes made on one of the paired tablets is send over Wifi to the HyPR device.

Infrastructure

Figure 7 shows the HyPR device infrastructure, which is an activity-aware patient management and information system designed to support multi-device location-aware collaborative workflows in patient wards. The infrastructure supports (i) large interactive screens for shared collaborative workspaces, (ii) tablet applications for mobile personalized tasks and detailed patient information, and (iii) desktop systems for integration with existing applications and services. The HyPR infrastructure is build on top of a generic distributed activity-centric infrastructure (detailed in [10]) that includes support for multi-device information management, context-awareness and ad hoc discovery and pairing of devices.

The infrastructure abstracts basic events, data, pairing, discovery and context services into a distributed *activity configuration*. These configurations connect all patient-related information resources, users and devices into one central reusable data model. This model is managed and distributed across all devices that are part of the same activity systems [10]. Devices such as tablets, pc computers, large displays are thus interconnected into one ad hoc distributed activity system, in which patient information is managed, synchronized and distributed as computational activity configurations. The hardware inside the HyPR device also connects to the infrastructure over Wifi and reports which tablet is detected. The infrastructure uses this information to push the right patient data to the paired tablet, or to update the properties of the HyPR device made through any of the connected devices.

Application

The HyPR application running on the tablet is a web-based stripped down electronic patient record that consists of a patient overview screen (Figure 8A) and a detailed patient record (Figure 8B). In the overview screen, all patients that are currently at the ward are listed with basic information including their name, medical procedure, assigned color and room number. Using this patient overview, clinicians can set to colored lights of a specific patient record to "blinking", thus asking for attention. Clinicians can also turn on the buzzing sound (which automatically stops after 15 seconds) of the record to quickly locate it when it is in a drawer or on a stack of other records.

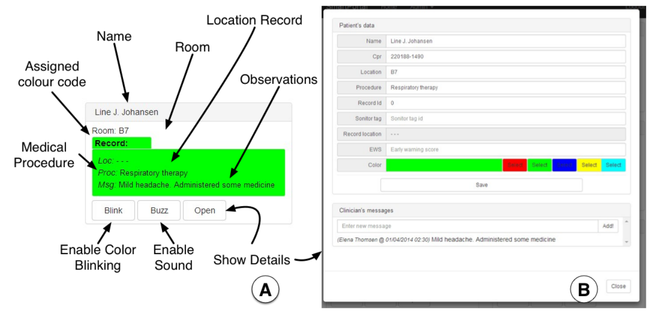


Figure 8. The details of the patient record.

The tablet is synchronized with the paper record through physical proximity. Placing the tablet on top of the paper record, automatically opens the detailed patient information of that patient to the tablet (Figure 8B). This view lists all detailed medical information and allows clinicians to add new medical data or messages. It can also be used to change the colored representation of the patient state. Changing this color in the details view updates the color on the HyPR device (Figure 4). When medical information is added remotely, through another tablet or computing device that is not physically paired to the paper record, the device's colored lights start blinking to signify an update. Once a clinician pairs the tablet, the new data is shown and the record stops blinking.

CLINICAL SIMULATION

To explore how clinicians would use the HyPR setup, we conducted a clinical simulation. Specifically, the study was set up to frame the use of the HyPR record within existing work practice as previously studied in the wards. In the medical domain, a clinical simulation is a frequently applied methodology used to train and educate clinicians in critical clinical scenarios, such as surgery, medicine prescription and administration, and emergency cases. It has proved very efficient and reliable for the initial phase of training and assessment of clinical staff [1]. Since the clinical simulation approach attempts to bring the dimension of clinical context into stronger focus, the method has lately been used also as a method for testing clinical systems with representative users doing representative tasks, in an ecological valid setting [12]. The goal of this simulation was to explore (i) the usefulness and usability of the HyPR device and (ii) the impact of HyPR devices on clinical work practices. Although a full description of the study is beyond the scope of this paper, we presents findings relevant to the system design of the HyPR device.

Study Setup

Over a period of 2 days, 8 clinicians (5 female + 3 male, mean age = 46, σ = 12,95) from three different wards (psychiatry, surgery, and emergency departments) participated in a clinical simulation. Participants included 5 doctors, 2 nurses and a psychologist. All clinicians were highly experienced in day to day medical work that involves managing and interacting with patient records, and rated themselves as experienced computer users ($\tilde{x}$= 4; *iqr*= 1). The clinical simulation was performed in a training–simulation ward that is identical to a full scale patient ward, and included both simulated patients (simulation dolls) as well as one human who was acting as a patient. The ward was organized and equipped as an oncology ward, but the scenarios were generic enough to be performed by clinicians with different clinical backgrounds. The study was conducted by two researchers, performing the roles of facilitator and observer.

Method

The study consisted of three phases. First, participants were introduced to the system and physical layout of the ward. After the introduction, participants were asked to complete three scenarios in pairs. The scenarios (that were based on observed situations from the field study) included (i) dual use, in which clinicians performed a ward round and calculated an early warning score (EWS) for four patients, (ii) recognizability and awareness, in which clinicians coordinated the arrival of a paper blood result, and (iii) mobility, in which clinicians searched for a lost record. Data from the scenario performances were captured by using video and audio recordings. Afterwards, participants completed a 5-point Likert scale questionnaire and an interview was conducted.

Results

Table 1 shows the results of the questionnaire on the usefulness of the final design and its specific features. The results of the questionnaire indicate that clinicians consider the final design of the HyPR device to be usable and useful in clinical work ($\tilde{x}$= 4,5; *iqr*= 1).

HyPR Usefulness (N=8)	*Min*	*Q1*	$\tilde{x}$	*Q3*	*Max*	*Iqr*
In general, the HyPR is useful	3	4	**4,5**	5	5	1
Pairing the PR and ER is useful	3	4	**4**	5	5	1
Color feature is useful	3	3,75	**4**	4,25	5	0,5
Tracking the PR is useful	4	4	**5**	5	5	1

Table 1. The results of the 5-point Likert scale questionnaire on the usefulness of the basic functions of a HyPR device. The table shows the minimum, maximum, median ($\tilde{x}$) and the inter quartile range (iqr) of the scores. PR:paper record; ER:electronic record.

Dual Use

The ability to simply place the tablet on top of the device to get instant access to digital data of a patient, was considered as very useful ($\tilde{x}$= 4; *iqr*= 1). During the ward round, almost all clinicians would immediately pair the device to the patient record, before actually checking the vital signs or talking to the patient. They thus preferred to configure and align both the electronic and paper record before commencing with assessing the patient. After this configuration, clinicians would often detach the tablet from the HyPR device. One clinician would typically hold the paper record to check the official early warning score (EWS) form, while the other clinician would check for messages on the tablet and add the EWS to the electronic record.

Although the feedback on the design of the HyPR device was more positive compared to the technology probe used during the design study, clinicians generally agreed that the device was still too heavy and too thick. In essence, they argued that for this device to be usable on a large scale, it has to be integrated in the paper record, thus being flat and flexible. There were also some issues with detecting the right HyPR device. When clinicians tried to pair the tablet with a HyPR device that was placed on a stack of other devices (e.g., Figure 4), the tablet would sometimes receive incorrect patient data. This opened discussion on security and privacy, as some clinicians mentioned that detailed access to patient data should be restricted to the assigned doctor and nurse. On the other hand, clinicians also saw the HyPR system as an opportunity to increase security. One suggestion was to actually physically lock the paper record to the HyPR enclosure until an authorized tablet is paired. This would ensure that only authorized browsing of the paper record would be possible.

Recognizability and Awareness

In general, most clinicians argued that using color was useful ($\tilde{x}$= 4; *iqr*=0,5) for coordination and communication between staff. During the scenarios, clinicians quickly adapted to using the color coding as part of the workflow. Although none of the clinicians felt that the color coding dictated a patient order for the ward round, most of them argued that having an extra layer of awareness on patient cases could improve coordination at the ward but also could help clinicians to reflect on their work. One doctor, for example, mentioned that the colors improved the structure of his round as they helped him prioritize patients. The blinking light feature when new critical messages were added to the electronic record received mixed responses. Some clinicians felt that using the colored lights on the record as a notification mechanism was very useful as they do not always carry a tablet when doing their work. Without the notification on the record, they felt that they might miss critical information. Other clinicians felt that the blinking colored lights were too distracting. Specially in cases where many records were in the same place, it could quickly escalate in a "Christmas tree".

During the interviews, the clinicians suggested a number of use cases for the color coding. One theme of suggestions was based around coordination between clinicians. Examples such as triage, allocation of nurses and even to reflect the current state of the patient, were proposed as use cases for dynamic colors. A common argument was that one color did not provide enough granularity to communicate more complex information and communication streams. Most clinicians agreed that more colored light indicators could be added to support more applications. A second theme of suggestions was based around patient involvement. One example proposed by clinicians was to use the lights as a road map or guide for the patient, so they could keep track of the different steps in their procedure. However, some clinicians also argued that using these colored lights might worry or even frighten patients who might be unaware of the significance of the changing color. One clinician suggested that the device should include a 'silent switch', that would turn of the visual and auditory notifications.

Mobility

Tracking the patient record was considered as one of the most useful features of the system ($\tilde{x}$= 5; *iqr*=1). During the scenarios, most clinicians would follow a similar pattern in which they would first find the room of the patient and the location of the record. They would then proceed to the location of the record, and if the record was not immediately visible they would start the blinking light. If the record still could not be located, they would turn on sound. Most clinicians argued that this was an important feature as patient records get lost regularly. The color blinking feature was useful to find a record in stacks of other records, but clinicians would mostly use the sound to find the record inside a room. Although some of the records were inside the patient room, we observed that clinicians would still use the sound indicator, even if patients were sleeping in that room. Most clinicians agreed that finding the record was important enough to disturb a patient.

A main point of criticism on the current system was the sound of the buzzer. Some of the clinicians suggested that rather than using "another medical sounding sound", the HyPR device could use radically different sounds such as a singing bird, as this would sound less stressful or disturbing for patients. Clinicians also proposed to use the location tracking capabilities in a more integrated way. Rather than "simply" tracking the record, they suggested to set up more advanced functionality such as e.g., automatically check-in when the patient and record arrive at the ward.

DISCUSSION

Often, the term *paperless workspace* points to a vision of a completely digitized work environment in which paper is replaced by digital devices. However, an increasing body of evidence indicates that despite increased digitization, paper is still an important resource in accomplishing everyday work and collaboration. This is true for office environments [22] but also for medical work in hospitals [17, 25, 33]. The central focus of the HyPR device prototype is to explore the functional and clinical design of an augmented hybrid medical record bridging across both the physical and digital records. Our design study and preliminary evaluation show that clinicians generally agreed that such a hybrid record would significantly improve the existing workflow. As such, the HyPR device could be viewed as part of a solution to two long standing problems in nomadic clinical work [3]: configuration and mobility work.

The HyPR device provides clinicians with a tool to synchronize and merge the paper and contextual digital representation of patient data, which significantly reduces *configuration work*, i.e. the amount of work required to setup a working context for a specific patient. The augmented record becomes an entry point into the digital patient record. Many clinicians argued that automatically loading patient data on the tablet when placed on top of the HyPR device, would significantly reduce this configuration work. The location tracking features of the HyPR device provide clinicians with a spatial coordination tool designed to help reduce *mobility work*. Using the wall-based displays, clinicians can look up and track the physical location of the device throughout the ward and the hospital, and the interface of the tablet provides *location awareness* cues on the location of the patient record.

The HyPR device is designed to support the highly collaborative workflow in hospitals. It supports *user multiplicity* by allowing multiple tablets to be connected to the same HyPR device. This allows multiple clinicians to work simultaneously on the same patient case – some using the paper record and some using the digital counter-part. This feature mimics the way that paper-based records are often shared among clinicians in colocated collaboration (e.g., by the bed side or during a medical conference).

One of the central limitations of the current approach, however, is the deliberate absence of digital support for separate paper documents and forms. Although the current design does not exclude the integration of Anoto or similar pens to automatically digitize written notes and forms, this would require a substantial change of existing hospital work practices. The paper forms and electronic records simply do not align one to one, thus posing fundamental questions on how these tools can be integrated and how they would effect work practices. Furthermore, our study showed that support for paper documents should in particular also incorporate support for handling legacy documentation for both legal and practical reasons. The HyPR provides support to *align*, not to *integrate*, information from the paper and digital records into one system. As such, the HyPR concept allows for a fluent and gradual approach to digitizing the entire medical work.

The current HyPR design still places a large emphasis on the use of a physical paper record, which is augmented for easy connections to the digital workflow. The form factor of the HyPR device leverages the shape of the paper record. This implies that at the cost of the weight of the back plate and electronics, the HyPR provides affordances (such as *flexibility*, *markability*, *portability*, and *accessibility* [8]) that are very similar to those of the paper record by itself. This allows clinicians to manipulate and use the HyPR in the exact same way as the paper record, thus embracing a number of existing practices. As with many electronic devices, the battery life of the device often limits its full potential. The current design of the HyPR allows for up to 6 hours of continuous use but includes a standard USB connector for easy recharging. However, for real long term deployment, this would not be a workable solution. Although battery use can be greatly optimized, digitizing mobile patient records will require the careful design of charging strategies that are mobile and fit into the existing workflows of clinicians that use the record.

The notion of a Hybrid Patient Record opens up a number of interesting questions for future work. HyPR devices could be augmented to support complex multi-device interactions including interactive whiteboards or desktop computers. Additionally, the role and design of printers can be re-thought: a printer could e.g., only print patient results when the record is physically moved into the nurse's station. Finally, the physical design of the HyPR device could consider a smaller and more flexible form factor embedded into the patient record binder.

CONCLUSION

In this paper, we introduced the novel concept of a Hybrid Patient Record (HyPR). Based on a field and design study, we presented the design and implementation of a HyPR device that supports (i) dual use, by allowing the pairing of the paper and digital information, (ii) recognizability, by allowing for dynamic color and sound coding of the record, and (iii) mobility, by using a portable form factor and location tracking. We presented initial feedback from a clinical simulation indicating that the HyPR device decreases configuration work, supports mobility in clinical work, and increases awareness on patient data.

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