Wearable Technology in Healthcare

Mike Krey, Ueli Schlatter, Devon Andruson Mahadevan, and Kevin Derungs
Zurich University of Applied Sciences, Winterthur, Switzerland
Email: {Mike.Krey, Ueli.Schlatter}@zhaw.ch, {Mahaddev, Derunkev}@students.zhaw.ch

Johannes Klaus Oehler
Bern University of Applied Sciences, Bern, Switzerland
Email: Johannesklaus.Oehler@students.bfh.ch

***Abstract*—Despite increasing reliability of data generated by wearable devices, not many institutions in the healthcare sector use wearables for patient care or safety. The benefit of having accurate patient data over a certain period of time is often neglected by the fact that the medical personnel and patients do not fully accept the technological improvement. Another issue is the interoperability between the device itself and the hospital information systems, e.g. data generated may not be further processed due to lacking data standards or interfaces. In order to investigate the acceptance of stakeholders of wearable devices, a survey based on use cases was sent out to medical and administrative staff of Swiss hospitals. Finally, a technical feasibility study was conducted to investigate the technical requirements and challenges for the integration of wearable devices in the hospital IT environment.**

***Index Terms*—wearable devices, healthcare, hospital information systems, Swiss hospitals, systems integration**

I. Introduction

Based on information of the KOF Swiss Economic Institute of the ETH University Zurich, healthcare costs have been increasing constantly on a high level and will continue to do so [1]. In order to save cost, it will be essential to find a way to work against this trend using new technologies such as wearable devices.

The general term *"wearable"* is used for devices, which tracks and sends data of their user in real time to a connected device using sensor technology. Wearables can also be used for medical purposes. They do not only track data about the physical condition of a person but also can give medical suggestions or provide information about the patient's health condition [2]. Wearables can be worn by the patient or implanted into the patient's body [3].

The University of London states that the conventional healthcare system can be improved by replacing monitoring systems with wearable devices [4]. These devices can not only be used as fitness trackers and calorie counters but have the potential to revolutionize healthcare. Through their capability of collecting large amounts of data and to communicate with other devices, they become a useful helper by monitoring patients with cardiac and circulatory troubles, diabetes or low blood sugar.

By constantly monitoring patient's health, the device can issue a warning as soon as the patient's health condition is being critical and prevent certain events like strokes from happening. Being not lager than an ordinary watch, wearables give users the ability to go through daily life without restrictions. Studies confirm that non-medical wearable devices like the Apple watch can already detect abnormal heart rhythm with 97% accuracy [5]. Nonetheless, there are still reasons why wearables have not yet become standard equipment in healthcare.

The systematic literature review conducted by Krey and colleagues revealed constraining and enabling factors of wearable technology in healthcare [6]. A total of 1'195 contributions have been analyzed. In a three-stage process, the relevant papers were identified by reviewing titles, abstracts and full text. The findings highlighted that wearables lead to an immediate increased physical activity and improved "quality of life" of the wearer [7]. Through position-based tracking via GPS[1] and the usage of accelerometers and gyroscopes, wearable user can track their physical activity of the day [8]. With the help of visualization tools and real-time monitoring, individuals can see their decision and doings, such as taking the stairs. This new and improved self-awareness can be an encouraging factor [9].

In addition the quality of treatments can be positively supported by monitoring patients at any location at any time [10], [11]. This allows contacting the medical response team immediately in case of an emergency. Combined with the feature of sending data directly to the relevant physician and or response team this does not only lead to better treatment decisions but also to awareness of any intolerances towards any medication [10]. In addition, sharing data can help provide new evidence about unknown symptoms and personal treatments [8], [12], [13].

In addition to quality of life and quality of treatment, data generated by the devices does no longer need to be evaluated by a human. By using machine learning certain patterns can be identified. This can be very useful to predict certain medical emergencies before they even occur [1], [14], [15]. Using a wearable allows to

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[1] Global Positioning System

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constantly follow the condition of a patient. However, the privacy of the patient is threatened by this constant surveillance. All information of the person is stored, analyzed and monitored [16]. Privacy plays an important role in the adoption of the wearable. If the perceived privacy risk is too high, people will not be using the devices. Nonetheless if the users see more benefits then risks (for e.g. the device could save their lives); users are willing to accept the constraining factors [17]. Another constraining factor is the fact that IoT devices were not built in mind of having security. The devices can be attacked and sensitive data may be stolen [18], [19]. Apparently, the power supply of these devices is often limited.

The research by Krey and colleagues revealed that product design is a relevant factor for using a wearable [6]. The acceptance and adoption of wearable technology in health is depending on factors like technology acceptance, health behavior, product design and privacy [2], [20]. For wearable devices built with the intention of medical usage the factors perceived expectancy, effort expectancy, self-efficacy, and perceived severity are relevant [2]. It can be stated that the reliability of a device indicates if it is an enabling or constraining factor for users and medical personnel. This includes safety, data accuracy, comfort in movement and portability of the device [21].

As stated in the systematic literature review by Krey and colleagues, patients and medical personnel must have some sort of acceptance towards the wearable device in order not to be a constraining factor [6]. For example, if physicians do not believe that a wearable device can monitor the patient reliably, they probably would not recommend sending the patient home early with a wearable device for monitoring [6].

Therefore, the paper at hand intends to discover how strong the stakeholder's acceptance towards wearable technology in healthcare is and which factors might be relevant. This will be done by caring out a survey with medical personnel and patients. In this survey, five use cases will be suggested. In a feasibility study it will be checked if the technology assigned to the use cases can be connected to a medical information system. Afterwards it will be evaluated what the technical requirements are to connect the device with the medical information system.

II. Objectives and Methodology

Due to the multitude of different options for a person's health status measurement, the line between wearables and medical devices has lost its preciseness. Patients can track their own personalized data, which ultimately leads to the question whether the recorded data is considered reliable and valid. To ensure the effective use of wearables in the healthcare sector, the collected data must always be valid and correct. A single deviation of data could have a considerable impact on a patient's health status; hence, not every device or sensor is useful in the healthcare environment. The following work strives for a deeper understanding of wearables in the healthcare sector.

The research question of this study is defined as follows:

"How high is the acceptance among physicians and patients for the use of wearables in healthcare?"

Subsequently, the following sub-research questions are answered:

1) Is the usage of wearable technologies in healthcare desirable?
2) Which is the most preferred use case for wearable devices usage?
3) Considering acceptance, is there a difference between health professionals and patients?
4) Which technical challenges need to be fulfilled to integrate a wearable device with a medical information system?

A sequential explanatory mixed method design is used to probe the study objectives. In order to expand and strength the study conclusion, a qualitative and a quantitative research approach are combined. First, a semi-structured survey, as a core component in mixed method was undertaken to collect quantitative data in order to gain more in-depth understanding of the acceptance and adaption of wearables in healthcare.

As a first step, the descriptive statistics of the overall use case acceptance is evaluated. Afterwards a t-test is conducted, which tests for different variances between groups. As a last step a correlation matrix is plotted in order to check if any correlation in the data can be found and if a logistic regression model can be used for the collected data sample.

Second, the supplemental component in mixed method, a feasibility study was conducted to investigate the technical challenges to interconnect a medical information system with a wearable device [22]. Information about the feasibility study is described in chapter 2 D.

A. Survey

In order to answer the sub-research questions 1-4 a survey with 34 questions was developed and evaluated. The questionnaire contains mostly closed questions with single or multi choice options or simple yes/no options. The questionnaire contains questions about the following topics:

- Personal information such as age, place of living and profession
- Questions about constraining factors
- Assessment of the five use cases selected for this study

One of the research questions investigates, if the acceptance between medical personal and patients towards wearables in healthcare is different; it includes a question in the beginning of the survey, which asks if the participant is currently working in the healthcare sector. This question divides the questionnaire so that people from the healthcare sector will have to answer additional questions about the use cases to find out if they would advise their patients to use a wearable. As the analysis is restricted to only German speaking countries, filter questions were added at the beginning if the participant is currently working in Germany, Austria or Switzerland.

Age, IT skills, and constraining factors such as trust in the reliability of data transmission or continuous observation of health data are playing an important role for the data analysis. Therefore, questions about these topics were added.

The last section of the survey contains questions about the use cases presented in Chapter 2 B. A Likert scale from 1 to 5 (from totally agree to totally disagree and vice versa) was used to measure the attitude against the use cases. The order of the scale was also switched regularly in order to receive enough data.

In addition to every question about the use case the participant could also state which point he/she finds problematic.

B. *Selection of Use Cases*

For the identification of relevant use cases a review of papers used in the systematic literature review about enabling and constraining factors was performed [6]. Simultaneously a review of potential wearable products on the market related to the use cases was done. The following use cases have been identified:

Use Case 1 - Blood Sugar Level: Continuous glucose monitoring (blood sugar monitoring) for patients in diabetes treatment. The wearable collects data about the blood sugar level and informs the user via app if further treatments are necessary [23].

Use Case 2 - ECG: Heart monitoring by using a wearable electrocardiogram (ECG). A patient prone to cardiac arrhythmia receives a wearable, which records the heartbeat. If the heart rhythm is deviates, the user will be contacted immediately [24].

Use Case 3 - Vitality Data: Real time monitoring of vital signs. The user of the wearable is monitored in real time. With this option, the patient is sent home from the hospital earlier. If the vital signs (pulse, temperature and heart rate) change significantly, the user will be contacted immediately [24].

Use Case 4 - Quality of Sleep: Diagnosis of sleep apnea and improvement of sleep quality. A wearable is used to identify the quality of the sleep and give an early diagnosis for sleep apnea. As soon as the sensors detect a deep sleep phase, adjusted low-noise audio tones stimulate the deep-sleep activity in the low-frequency range and thus provide a better sleep quality [25].

Use Case 5 - Pregnancy Forecast: Fertility and pregnancy tracking via wearable. The wearable collects data about physiological parameters of woman and detects the fertile window. The user can use this data for pregnancy planning [26].

C. *Data Collection*

In order to make a valid statistical evaluation the authors gathered as many participants as possible in the time of six weeks. Therefore, the questionnaire was sent to ten different hospitals. It was also posted on social networks such as LinkedIn and Xing and sent to their personal relatives. All participants were emailed personally with the link of the survey and a short description about the objective.

D. *Feasibility Study*

The purpose of this feasibility study is to understand the technical challenges that will face the integration between a defined wearable device and a medical information system. In general, a feasibility study is a kind of research, which is conducted before a main study will be designed. It can be used for evaluating five different areas, such as technique, economy, legal, operational and scheduling. Furthermore, a feasibility study is used to find important parameters for further studies [27]. In this research, a technical feasibility study is most appropriate as the research team must examine the integration of two software components.

The outcome of the survey should indicate which use case and which wearable device will be ranked positive and useful by the participants. The wearable device will be selected for the technical feasibility study. As counterpart software, the CuraMed medical information system has been selected. One factor to choose CuraMed is the available information procurement and market position of this product.

III. Study Results

A. *Descriptive Statistics*

Overall 59 participants filled out the questionnaire. All outliners and samples that with missing values where omitted so that a total of 46 samples for the evaluation of the survey remained. Furthermore, only German speaking individuals were considered for this questionnaire. All statistic evaluations were conducted in R Studio. The results of the descriptive evaluation can be seen in Table I, which considers both people working in healthcare and other sectors. The range of the table is from 1 to 5 (1 = the person strongly agrees to the treatment; 5 = the person does not agree at all). As described in chapter 2 A the table resulting from 1 to 5 was inverted in some cases in order to get reliable data. For the analysis all use case data was changed as follows: The value 1 is stated as totally agree, the value 3 is stated as neutral and value 5 is stated as totally disagree with the use case. As seen in Table I the feedback resulted in a positive rating for all use cases except for pregnancy forecast, even though ECG and blood sugar use cases, were rated higher than others.

TABLE I. Descriptive Statistics of Use Cases (1 = Totally Agree, 5 = Do Not Agree at all)

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Sd
Bloodsugar	1.000	1.000	2.000	2.205	2.250	5.000	1.4719
EKG	1.000	1.000	2.000	2.273	3.000	5.000	1.168653
Vitality data	1.000	2.000	3.000	2.591	3.000	5.000	0.995762
Quality of sleep	1.000	1.000	2.000	2.409	3.000	5.000	1.317471
Pregnany forecast	1.00	2.00	3.00	3.25	5.00	5.00	1.511583

1) *Use case 1: Blood sugar level*

Overall the use case for tracking blood sugar levels is rated the highest with a mean of 2.205 and seems to provide the most usefulness to people. Most participants would consider this therapy rating it as one (I strongly agree) or two (I agree) and 56% do not see any negative aspects about this treatment. However, it also has a high standard deviation with 1.4719. Looking at the negative aspects of this the continuous data transfer has the most impact on negative attitude towards the use case. Only four people don't trust the wearable.

2) Use case 2: ECG

This use case is the rated almost as meaningful as use case 1 with a mean of 2.273. Also, the standard deviation for this use case is lower than in the measurement of blood sugar. This shows that the participants have a similar opinion that the usage of an ECG wearable would be a very useful way of therapy. 43% of all participants state no negative aspect about this use case. The most negative aspect measured about this use case is the continuous data transmission, followed by unpractical to use.

3) Use case 3: Vitality data

Compared to the first two use cases this use case is rated much lower with a mean of 2.591. The standard deviation in this use case is the lowest of all five, which shows that people are in general less interested in this kind of therapy. Almost 30% answered that the continuous data transfer is a negative aspect but also 16% issued no trust against the wearable. Considering that fitness wearables record vital data and have been on the market for several years, this still seems to be an issue. Nonetheless, most participants see no negative aspects for the usage of this wearable and the overall acceptance is high.

4) Use case 4: Quality of sleep

For the recording of data during sleep the overall acceptance is a bit higher as in use case 3 but still less than for use case 1 and 2. The standard deviation is also less than in the first two use cases. An overall number of 1.3 still shows that people have different opinions about this. Like all use cases participants indicated that the data transmission is the most negative aspect about this followed by no trust towards the wearable and that the wearable is unpractical to wear.

5) Use case 5: Pregnancy forecast

This use case has the lowest score of all use cases and does not appear to be very useful for participants with a mean of 3.25. The 3rd quartile of this use case is set on 5. This shows that many people rated this use case as not useful at all. The standard deviation on this use case is also the highest, indicating that there are different opinions about the usefulness of this use case. However, from all use cases this was the only one where people did not rate continuous data transmission as a negative aspect. Almost 30% rated personal dislike as negative point which shows, that the overall acceptance of this use case is very low.

6) Summary

The evaluation of the use cases in general shows, that both medical personnel and people who do not work in the health sector see wearables in healthcare as positive. None of the use cases except for pregnancy forecast have a mean rating of more than 3, which shows that 4 of 5 use cases find high acceptance in the sample. Therefore, the first research question, if the use of wearable technologies in health care is desirable can be answered with yes. Even though more than 75% of the participants were unaware or did have very little knowledge that wearables can be used for health care. Most people reacted rather positive to the different use cases. The evaluation also answered the second research question about the most preferred use case with wearable technology. Both the use cases blood sugar and ECG gained very high acceptance ratings from participants of the survey.

7) Statistical analysis: Variance

After the descriptive evaluation, the next phase is to understand if there is a difference in variance between people working in the health sector like doctors and nurses and people working in different sectors. A t-test was conducted for all use cases. The H0-hypothesis states that there is no significant difference between groups. The variables use case 1- use case 5 are set as dependent variables. The variable in health sector, (person that works in the health sector) is set as a dummy variable. The results of the tests are displayed in Table II.

TABLE II. T-TEST

	t	df	p-value
Bloodsugar	0.40581	42	0.6869
EKG	-0.32398	42	0.7476
Vitality data	-0.55692	42	0.5805
Pregnancy forecast	-0.53083	42	0.5983
Quality of sleep	-0.55383	42	0.5826

The t-test results show that for no group there is a significant variance in group (p>0.005). Therefore, the H0-Hypothesis that health professionals have the same attitude as patients can be accepted for all five use cases and the third research question, which asked between differences in groups can be negated.

The next step is the analysis of the data for correlation. The following independent variables were created:

- Age (continuous variable)
- In Healthcare (1 = yes, 0= no)
- IT know how (1 = highly skilled, 5= no IT skill)
- Data security (5 = very important, 1 = not important at all)
- Recently treated (1 = yes, 0 = no)
- Lifelong therapy (1 = yes, 0 = no)
- Data observation (1 = plays a high role, 5 = does not play a role)

For the dependent variable acceptance, a median split was conducted to create a new dependent dummy wearable acceptance (Median 2.2, value <2.2 = accepts wearable technology, value >2.2 does not accept wearable).

However, the correlation between the variables was very week and can be seen in the correlation matrix in Fig. 1, which was created in R.

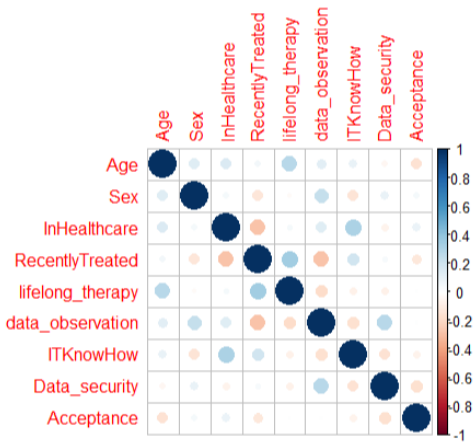

Figure 1. Correlation matrix

Even though there is low correlation between some variables, the results of the regression resulted in a R^2 of around 0.02, which only explains 2% of the variances. The reason is that authors primary aimed to gather information about which use cases would provide the most use to patients. Due to the short time to gather a sample it was not possible to gather enough data for a logistic regression with decent results. A logistic regression would have given further insights, how and if the coefficients of the dependent variables have a positive or negative influence on the acceptance (p for 1 = accept technology of wearable technology; 0 = does not accept).

8) Use case selection for technical feasibility study

After the evaluation of the use cases, the next phase was to choose a use case for the technical feasibility study. The criteria for the selection were the following:

- The use case must have high acceptance from the sample
- The wearable must be FDA approved
- The wearable must already be available on the market
- The retailer must be willing to share information about the wearable (e.g. interfaces)

The use case with the highest acceptance was the wearable technology measuring blood sugar in patients. Unfortunately, the retailer did not want to share any information about the wearable itself and the wearable is also not available for purchase yet. Therefore, the use case ECG was selected for the feasibility study. With a mean value of 2.273 the acceptance was only a little lower than the use case blood sugar. Furthermore, the median of both use cases was identical, and the standard deviation of the ECG use case was lower, so that the use case provides very high acceptance as well. The wearable technology for this use case is already purchasable and also FDA approved, so that the technical feasibility study can provide the first step for a prototype in the future.

In the following chapters the feasibility study, the selected wearable and the medial information system it can be connected to are described in detail.

B. Technical Feasibility Study

The aim of this technical feasibility study is to indicate which major technical challenge must be faced for an integration of a wearable device with a medical information system. Therefor both components were investigated in relation to product functionality, existing technical interfaces and future challenges.

1) AliveCor

Kardia Band is a wrist-band ECG reader, provided by the company AliveCor. They are manufacturing medical device and specialized in artificial intelligence. They are one of the first companies to receive FDA-clearance for their wearable device in combination with an Apple Watch. AliveCor offers more than one wearable device, the Kardia Band and Kardia Mobile. In addition, they provide an internet portal dedicated for health professionals. It visualizes all patients with use of Kardia Band or Kardia Mobile [28]-[30].

a) Kardia Band

The *Kardia Band* is a wrist-band ECG reader (cf. Fig. 2). It can be used as a wristband for Apple Watch. The FDA-clearance for Kardia Band was issued in 2017. With the built-in sensor in the wristband and the software "Smart Rhythm" installed on Apple smartphone, analysis the heartrate continuously with use of artificial intelligence. The device can detect pattern, such as atrial fibrillation from normal sinus rhythm. The detection algorithm was approved by the FDA.

Figure 2. Kardia Band [29]

Furthermore, the Smart Rhythm application can understand unusual pattern of signals. It sends an alert to the user and requests to take a 30-second ECG over the in order to confirm the pattern. The Kardia Band can also do full ECG readings and share it with physicians in PDF format. The Kardia Band works only in combination with Apple Watch and therefore it is only available in the AppStore of Apple. In contrast, it has no application interfaces to connect to 3rd party applications [29].

b) Kardia Mobile

Kardia Mobile is alternative ECG reader to the *Kardia Band*. It is a wearable device that cannot only be used with Apple Watch. But it is also able to connect with Android and iOS smartphones. The device works by placing the fingertips on a gum-stick sized device. Essentially the way it functions is the same as Kardia Band with the Apple Watch [30]. The Kardia Band was already FDA-cleared in 2012 for the machine learning algorithm. In addition to ECG, it can track palpitations, shortness of breath, dietary habits, sleep and exercise patterns [31]. Already a lot of research has been done with the device regarding accuracy of algorithm or the comparison with standard 12-lead ECG devices. A study conducted in October 2018 evaluated the accuracy of atrial fibrillation detection of the Kardia Band. A sensitivity of 96.6% and a specificity of 94.1% was measured compared to a 12-lead electrocardiogram [32]. Another study investigated the use of Kardia Band in pediatrics and concluded a very high acceptance and patient satisfaction due to simplicity and effectiveness of the device [33].

c) KardiaPro

As a product for clinicians, KardiaPro connects Kardia Mobile and Kardia Band patients together (cf. Fig. 3). It gives the clinicians the possibility with an artificial intelligence-enabled technology to monitor their patients in real-time. On a patient-by-patient dashboard the doctor sees a flow of all ECG data. In addition to that, the platform can inform the responsible person if an abnormality is detected. As the KardiaPro platform is cloud-based it can also indicate signs of an oncoming stroke by using artificial intelligence. Furthermore, the product Omron, a small blood pressures monitor can also be connected to KardiaPro. Overall KardiaPro is remote patient monitoring system that gives the clinicians the possibility to review patient ECG data without a patient visit [34], [35].

Figure 3. KardiaPro - Remote patient monitoring system [34]

2) Description of curaMED product

curaMED is medical information system for doctors as well as doctor’s practices and clinics. It is developed by Swisscom Health AG. All Information about curaMED was gathered through product documentation and several interviews with Application Managers. curaMED is used for day-to-day work of a doctor. It allows to document patient demographics, medical information, patient appointment scheduling and all others task around a medical treatment and medical billing. curaMED is a „SaaS “-Software solution (Software as a Service), that means in it not installed onsite in doctor’s IT environment, instead it is available through the internet via a secure connection. The benefit of such software solution is the zero-maintenance expense. In addition to that, curaMED is modularly designed. If a doctor isn’t doing medication at the clinic, the application can be adjusted individually.

Furthermore, curaMED uses for patient communication another product called Evita. This product is used to share patient documents and communicate with the patient itself. In addition, medical devices such as laboratory equipment and ECG can be connected to curaMED.

3) System integration via application programming interface

In IT the process of connecting to different applications systems together is defined as system integration. There are four level of system integration: data, application, user and process-level integration (cf. Fig. 4).

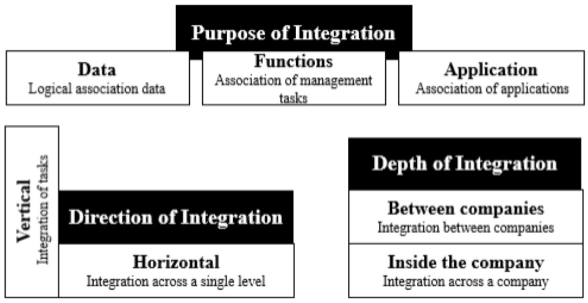

Figure 4. Views of integration [36]

This feasibility study focuses on application integration. The main objective of application integration is to avoid information silos between applications. There is two kind of basic application architecture, which is appropriate to face a system integration. One is the star architecture and one the bus architecture. In star architecture the applications are service oriented, so called SOA, Service Oriented Architecture. These systems are based on services which are communicating through API[2] interface to exchange data [36]. It allows communicating from an application to another application like internet of things as well as use of mobile devices, like wearable accelerated the use of API.

Recent industry standards are Representational State Transfer (REST), Simple Object Access Protocol (SOAP), and Hypertext Transfer Protocol/secure (HTTP/S) [37]. The common standard for data exchange in health care IT is Health Level Seven (HL7). HL7 is a set of international standards for the transfer of clinical and administrative data between different software components. It is developed by the Health Level Seven International, a non-profit organization. There are different versions of HL7 standards. HL7 version 2.x is the widest used one. HL7 Version 3.0 is based on XML and relies on objects. Another standard also from HL7 is FHIR. This standard is web-based and uses XML and JSON as data format [38].

a) HL7 aECG

Electrocardiograms, ECG, are biomedical data, used for measuring heart activity in cardiology. The structure of ECG data was standardized by different initiatives. And one of these standards is HL7 aECG [39]. By order of FDA the HL7 community created the annotated ECG (aECG) HL7 standard in November 2001. The purpose was to evaluate systematically ECG waveforms as most

[2] Application Programming Interface

of the ECG at this time were collected on paper and not electronically [40]. Furthermore, this standard gives the possibility to evaluate structured data, as it is useable for analytic purposes and research. Therefore, aECG is the standard format for ECG data and should be used for integration.

4) AliveCor – Current state

The company provides for strategical partners standard application interfaces for data exchange with 3rd party software. Furthermore, a standard application interface allows 3rd party software to manage patients in KardiaPro and retrieve ECG data from wearable devices such as Kardia Band and Kardia Mobile. The data format is JSON Protocol. JSONS stands for JavaScript Object Notation and is used as an open-standard file format. JSON is often applied in case of an asynchronous browser–server communication [41].

Regarding HL7 Interface there were no information currently, according to the Vice President, HL7 could be developed in the future. In summary, AliveCor can only export PDF files and has no API Interface for common use.

5) curaMED – Current state

CuraMED is already using and providing application interfaces. For instance, laboratory equipment could be connected through the product LabCube. This is hardware box which is connected to laboratory devices and same time it can communicate with curaMED. The data transfer from laboratory device to CuraMED is handled by LabCube in HL7 or PDF format. curaMED is a service-oriented application. It has an API interface and can communicate through REST, HL7 and SOAP. Another application interface with curaMED is the GTD interface. The GDT interface is developed by FirstSoft GmbH in Germany. Through this interface ECG devices are connected to curaMED. The GDT interface has also the possibility to communicate in the standard HL7 format [42], [43]. The current state of curaMED has a high maturity regarding integration of an ECG wearable device.

6) Challenges

Today, there are technical challenges for medical information system and wearable manufacturer in integrating wearable technology in health care. As wearable technologies bring new information about the patient for health professionals the ability to collect this continuous data is needed. Most of the existing wearable tools are not integrated to the medical information systems. That leads the doctors to access the wearable system separately, which requires additional time, education and training and increased workload [44]. To overcome this challenge the data sharing between both systems must be enabled. The doctors should be able to extract wearable data directly from his medical information system, which is interconnected with the wearable device or wearable platform (cf. Fig. 5). In technical terms, HL7 standard and REST technology could be used to integrate both systems optimal. The incentives from wearable manufacture AliveCor is in place to provide a HL7 and REST Interface in future. On the other side, curaMED is prepared to handle HL7 data through REST Interface.

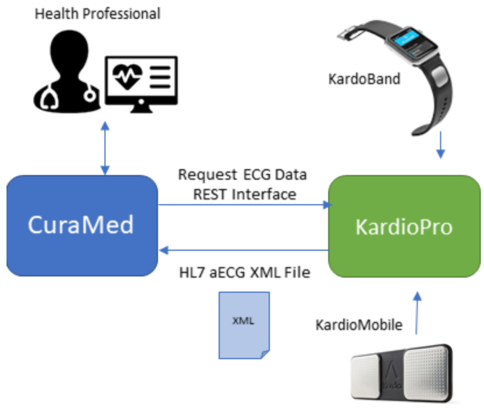

Figure 5. REST & HL7 integration

Another option to integrate a wearable from AliveCor with curaMED is an IFRAME integration with Single Sign On, SSO. An IFrame is a HTML website or a document on the internet which is embedded inside another HTML website. As curaMED and KardiaPro are web-based application an IFRAME integration is possible without big technical effort. [45]. Furthermore, to avoid a second login process from curaMED to KardiaPro, the SSO feature could be implemented. With SSO a single login in curaMED permits the user to access an independent software system like KardiaPro [46]. As this option is not a system integration, it requires both companies less development effort as the first option.

However, one of the important technical requirements to integrate a wearable into a medical information system is the agreement to use a standardized common interface.

IV. Conclusion and Discussion

Wearable technology can provide an important step for the future of healthcare in Switzerland. In this paper research was conducted to find the most accepted use cases for both patients and health care professionals. The evaluation of data showed that

- The use cases ECG and blood sugar have the highest acceptance. Even though both have a high standard deviation, not all participants share the same opinion about the acceptance. With a mean value of 2.205 and 2.273 most patients and health professionals would consider such therapy useful and in both cases the majority didn't see negative aspects in those use cases.
- The use cases quality of sleep and vitality data both have a good acceptance rate as well and most people would also recommend such therapy or try it for themselves. Some negative aspects were thoughts about the wearables not being practical in daily life but mostly no negative aspect was mentioned.
- The use case pregnancy forecast has a very low acceptance from both groups, and it would not be a valid option for most of the people. Almost 30% issued personal dislike toward this use case.

Whereas the personal dislike rate was not higher than 5% in the other use cases of this survey.

- There is no variance between groups and both medical personal and none health professional share the same opinion about wearable technology. Considering the high standard deviation of >1 it also shows, that both groups do not fully share the same opinion as a small sample was always rated with 5, which meant not useful at all.
- For all use cases the highest negative aspect was mostly the permanent data observation. Data privacy is for almost every participant a very sensitive aspect and needs to be respected.

Next steps for future research would a bigger sample so that regression analysis can explain the most important dependent variables for both constraining and enabling factors of wearables and how big the coefficients´ influence is on the acceptance of wearables. Interesting variables for this could be the variables suggested in this paper. For statistic evaluation a bigger sample should be selected, and the survey needs to be operationalised with items aiming for deeper knowledge of those factors.

Furthermore, in the technical feasibility study, the technical challenge how to integrate AliveCore Kardia Band wearable with the medical information system curaMED was analysed. However, in an application integration project in which two independent systems should be interconnected, the question on which level the integration should be cleared beforehand.

In this research paper two variations of integration were presented. First, an application integration based on the system integration theory was evaluated. Second, a HTML IFrame integration with SSO Login was assessed. Both options require software development works. In case of an application integration the REST interface technology is suggested by the research team, as this technology is mostly used in current web applications. Regarding the format of exchange data, HL7 aECG standard fulfils all requirements for the healthcare sector.

The HTML Iframe integration is a not based on the system integration theory. Therefore, no connection between two application is established. One application calls the second application, in between no data is exchanged. If the HTML Iframe integration is combined with SSO, it can reduce the login step on the second application.

With the help of this feasibility study further research can be conducted in form of a first prototype that connects CuraMed and KardiaPro.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Devon Andruson Mahadevan, Kevin Derungs and Johannes Klaus Oehler conducted the research and analyzed the data; Mike Krey and Ueli Schlatter corrected the paper; all authors had approved the final version.

References

[1] NZZ. 2018 dürfte jede Person erstmals über 10 000 Franken für ihre Gesundheit ausgeben. [Online]. Available: https://www.nzz.ch/schweiz/gesundheitskosten-in-der-schweiz-2018-duerfte-jede-person-erstmals-ueber-10-000-franken-fuer-ihre-gesundheit-ausgeben-ld.1300609

[2] Y. Gao, H. Li, and Y. Luo, "An empirical study of wearable technology acceptance in healthcare," *Industrial Management & Data Systems*, vol. 115, no. 9, pp. 1704-1723, 2015.

[3] E. L. Mahoney and D. F. Mahoney, "Acceptance of wearable technology by people with Alzheimer's disease: Issues and accommodations," *American Journal of Alzheimer's Disease and Other Dementias*, vol. 25, no. 6, pp. 527-531, 2010.

[4] T. Yilmaz, R. Foster, and Y. Hao, "Detecting vital signs with wearable wireless sensors," *Sensors*, vol. 10, no. 12, pp. 10837-10862, 2010.

[5] Juli Clover. Study confirms apple watch can detect abnormal heart rhythm with 97% accuracy. [Online]. Available: https://www.macrumors.com/2018/03/21/apple-watch-abnormal-heart-rhythm/

[6] M. Krey, "Wearable device technology in healthcare: Exploring constraining and enabling factors," in *Advances in Intelligent Systems and Computing*, Springer, 2020.

[7] S. J. Strath and T. W. Rowley, "Wearables for promoting physical activity," *Clinical Chemistry*, vol. 64, no. 1, pp. 53-63, 2018.

[8] J. Lee, *et al.*, "Sustainable wearables: Wearable technology for enhancing the quality of human life," *Sustainability*, vol. 8, no. 5, p. 466, 2016.

[9] S. H. Koo and K. Fallon, "Explorations of wearable technology for tracking self and others," *Fashion and Textiles*, vol. 5, no. 1, p. 141, 2018.

[10] U. Varshney, "Pervasive healthcare and wireless health monitoring," *Mobile Networks and Applications*, vol. 12, no. 2-3, pp. 113-127, 2007.

[11] M. Blount, *et al.*, "Remote health-care monitoring using personal care connect," *IBM Systems Journal*, vol. 46, no. 1, pp. 95-113, 2007.

[12] P. Kostkova, *et al.*, "Who owns the data? Open data for healthcare," *Frontiers in Public Health*, vol. 4, p. 7, 2016.

[13] J. Sun, *et al.*, "mHealth for aging China: Opportunities and challenges," *Aging and Disease*, vol. 7, no. 1, pp. 53-67, 2016.

[14] L. Clifton, *et al.*, "Predictive monitoring of mobile patients by combining clinical observations with data from wearable sensors," *IEEE Journal of Biomedical and Health Informatics*, vol. 18, no. 3, pp. 722-730, 2014.

[15] J. Couturier, *et al.*, "How can the internet of things help to overcome current healthcare challenges," *Communications & Strategies*, vol. 3, pp. 67-81, 2012.

[16] M. Milutinovic and B. D. Decker, "Ethical aspects in eHealth – Design of a privacy-friendly system," *Journal of Information, Communication and Ethics in Society*, vol. 14, no. 1, pp. 49-69, 2016.

[17] H. Li, *et al.*, "Examining individuals' adoption of healthcare wearable devices: An empirical study from privacy calculus perspective," *International Journal of Medical Informatics*, vol. 88, pp. 8-17, 2016.

[18] M. Zhang, A. Raghunathan, and N. K. Jha, "MedMon: Securing medical devices through wireless monitoring and anomaly detection," *IEEE Transactions on Biomedical Circuits and Systems*, vol. 7, no. 6, pp. 871-881, 2013.

[19] M. H. Maras, "Internet of things: Security and privacy implications," *International Data Privacy Law*, vol. 5, no. 2, pp. 99-104, 2015.

[20] N. D. Weinstein, "Testing four competing theories of health-protective behavior," *Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association*, vol. 12, no. 4, pp. 324-333, 1993.

[21] H. S. Koo, *et al.*, "Design preferences on wearable e-nose systems for diabetes," *International Journal of Clothing Science and Technology*, vol. 28, no. 2, pp. 216-232, 2016.

[22] J. Schoonenboom and R. B. Johnson, "How to construct a mixed methods research design," *Kolner Zeitschrift Fur Soziologie Und Sozialpsychologie*, vol. 69, suppl. 2, pp. 107-131, 2017.

[23] G. Cappon, *et al.*, "Wearable continuous glucose monitoring sensors: A revolution in diabetes treatment," *Electronics*, vol. 6, no. 3, p. 65, 2017.
[24] A. K. Yetisen, *et al.*, "Wearables in medicine," *Advanced Materials (Deerfield Beach, Fla.)*, p. e1706910, 2018.
[25] Philips. Philips SmartSleep. [Online]. Available: https://www.philips.de/c-e/hs/sleep-solutions/smartsleep-advocacy.html
[26] Avawomen. Tracke deinen Zyklus mit Ava. [Online]. Available: https://www.avawomen.com/de/tracking/
[27] Oregon State University. What is the difference between feasibility studies and pilot testing? [Online]. Available: https://research.oregonstate.edu/irb/what-difference-between-feasibility-studies-and-pilot-testing
[28] AliveCor. Take an EKG anytime, anywhere. [Online]. Available: https://www.alivecor.com/how-it-works/
[29] AliveCor. KardiaBand system - Instructions for use. [Online]. Available: https://www.alivecor.com/ifus/kardiaband/15LB1.5-en.pdf
[30] AliveCor. Kardia Mobile - Instructions for use. [Online]. Available: https://www.alivecor.com/ifus/kardiamobile/02LB49.2-en.pdf
[31] AliveCor. Kardia – User Guide. [Online]. Available: https://www.alivecor.com/previous-labeling/kardiamobile/00LB19.3%20German.pdf
[32] A. D. William, *et al.*, "Assessing the accuracy of an automated atrial fibrillation detection algorithm using smartphone technology: The iREAD study," *Heart Rhythm*, vol. 15, no. 10, pp. 1561-1565, 2018.
[33] M. Macinnes, *et al.*, "Comparison of a smartphone-based ECG recording system with a standard cardiac event monitor in the investigation of palpitations in children," *Archives of Disease in Childhood*, vol. 104, no. 1, pp. 43-47, 2019.
[34] AliveCor. The remote patient monitoring platform that doesn't waste your time. [Online]. Available: https://clinicians.alivecor.com/
[35] AliveCor. The most clinically-validated personal ECGs in the world. [Online]. Available: https://clinicians.alivecor.com/our-devices/
[36] M. Péči and P. Važan, "Choosing the right systems integration," *Research Papers Faculty of Materials Science and Technology Slovak University of Technology*, vol. 22, no. 35, pp. 23-30, 2014.
[37] *Application Performance Management (APM) in the Digital Enterprise*, Elsevier, 2017.
[38] Wikipedia. Health Level 7. [Online]. Available: https://en.wikipedia.org/wiki/Health_Level_7
[39] B. Gonçalves, G. Guizzardi, and J. G. P. Filho, "Using an ECG reference ontology for semantic interoperability of ECG data," *Journal of Biomedical Informatics*, vol. 44, no. 1, pp. 126-136, 2011.
[40] B. D. Brown and F. Badilini. HL7 aECG Implementation Guide. [Online]. Available: http://www.amps-llc.com/uploads/2017-12-7/aECG_Implementation_Guide(1).pdf
[41] Wikipedia. JSON. [Online]. Available: https://en.wikipedia.org/wiki/JSON
[42] AMT-Abken. GDT Schnittstelle – Was Sie Aussagt. [Online]. Available: https://www.amt-abken.de/gdt-schnittstelle-was-sie-aussagt
[43] First Soft GmbH & Co.KG. GDT Schnittstelle für Medizingeräte. [Online]. Available: https://www.first-soft.de/gdt-schnittstelle/
[44] H. Lewy, "Wearable technologies – Future challenges for implementation in healthcare services," *Healthcare Technology Letters*, vol. 2, no. 1, pp. 2-5, 2015.
[45] WhatIs.com. IFrame (Inline Frame). [Online]. Available: https://whatis.techtarget.com/definition/IFrame-Inline-Frame.
[46] V. Radha and D. H. Reddy, "A survey on single sign-on techniques," *Procedia Technology*, vol. 4, pp. 134-139, 2012.

Mike Krey is lecturer at the Zurich University of Applied Sciences (ZHAW) in Switzerland. He is involved in research projects in the fields of business process management and automation. His previous positions include, among others, business development manager for IT solutions in the health care sector and project manager for software development projects for T-Systems in Germany. His education is based on a Master of Science in eBusiness and a PhD awarded by the Plymouth University (UK), School of Computing and Mathematics.

Ueli Schlatter was born in Schaffhausen, Switzerland. He received the MSc degree in Business Administration from the University of Sankt Gallen. He works as lead lecturer in Enterprise Information Systems at the Institute of Business Information Technology, Zurich University of Applied Sciences (ZHAW) in Switzerland. He has led various projects in the area of Business Process Management and has published research papers at national and international journals on various topics, mainly in the healthcare and information technology sector.