GLOBAL HEALTH 2012

The First International Conference on Global Health Challenges

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GLOBAL HEALTH 2012 Editors

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GLOBAL HEALTH 2012

Foreword

The First International Conference on Global Health Challenges [GLOBAL HEALTH 2012], held between October 21-26, 2012 in Venice, Italy, took a global perspective on population health, from national to cross-country approaches, multiplatform technologies, from drug design to medicine accessibility, everything under mobile, ubiquitous, and personalized characteristics of new age population.

Recent advances in technology and computational science influenced a large spectrum of branches in approaching population health. Despite significant progresses, many challenges exist, including health informatics, cross-country platforms interoperability, system and laws harmonization, protection of health data, practical solutions, accessibility to health services, and many others. Along with technological progress, personalized medicine, ambient assistance and pervasive health complement patient needs. A combination of classical and information-driven approach is developing now, where diagnosis systems, data protection mechanisms, remote assistance and hospital-processes are converging.

We take here the opportunity to warmly thank all the members of the GLOBAL HEALTH 2012 Technical Program Committee, as well as the numerous reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and efforts to contribute to GLOBAL HEALTH 2012. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

Also, this event could not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the GLOBAL HEALTH 2012 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope that GLOBAL HEALTH 2012 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in the field of global health.

We are convinced that the participants found the event useful and communications very open. We also hope the attendees enjoyed the charm of Venice, Italy.

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***Abstract*—Preterm neonates often suffer from pain, distress and discomfort during the first weeks of their lives. While residing in special Neonatal Intensive Care Units (NICUs) that are designed for optimal care, they are subject to numerous interventions ranging from a simple diaper change to surgery. Although pharmacological pain treatment often is available, it cannot always be applied to relieve a neonate from pain or discomfort. Therefore, new non-pharmacological solutions are required to reduce the discomfort experienced by these babies during the first weeks of their lives. This paper describes a novel solution, called Mimo, that provides comfort through mediation of a parent's physiological features to the distressed neonate. We discuss the design and the implementation and pilot-evaluation of a first prototype. Results show that the concept is promising enough to pursue a full-scale clinical trial.**

***Index Terms*—preterm neonates; comforting solution; bonding; heartbeat; pillow; user-centered design;**

I. Introduction

Premature infants, born after a gestational age of less than 32 weeks are admitted to a Neonatal Intensive Care Unit (NICU), where they are nursed in an incubator and receive medical treatments. The last decades many new therapies have been introduced, resulting in a substantial improvement of survival. However, the stay of a preterm infant in the incubator is negatively influenced by stress (excessive light and noise) and painful procedures [1]. Gradually, the insight is growing that these factors are partly responsible for developmental impairments [2]. The Eindhoven University of Technology (TU/e) in the Netherlands has started collaboration on research with the Maxima Medical Centre in Veldhoven, the Netherlands. The goal of this project is to improve well being for the pregnant woman and her child before, during and after delivery [3]. Research results that have been reported from this project area, for example, a smart jacket for neonates integrated with textile sensors [4], a power supply based on contactless energy transfer [5], blood oxygen saturation monitoring for neonates using a reflectance pulse oximeter [6], neonatal temperature monitoring [7], data transmission [8], and a device to support cardiopulmonary resuscitation of neonates [9], [10]. Within this project, this paper presents the pilot-study of a novel, non-pharmacological comforting solution for preterm neonates.

A. Pain and discomfort

Premature neonates residing at Neonatal Intensive Care Units (NICUs) experience much pain and discomfort due to necessary medical interventions. These interventions include, but are not limited to: heel punctures, venepunctures and in- or detubations [11]. The attachment and removal of sensors required for measuring physiological body signals can also be unpleasant, stressful and painful [12]. Although pain treatment is given in some of these cases, a large proportion (50%) [11], [13] of the interventions are performed without any form of pain treatment.

Simple procedures and environmental factors are also possible sources of pain and discomfort to preterm neonates. Nociception is the term used to refer to the neural processes of encoding and processing painful stimuli. In preterm neonates this nociceptional system is not yet fully developed. A possible consequence of this not-fully developed nociceptional system is that stimuli such as sound and light, which are normally not considered painful to a human being, may be perceived as painful by the preterm neonate [14]. Injuries, but also clinical procedures, will result in more widespread sensitivity to pain [15]. The consequences of untreated procedural pain in neonates can be both severe and long term. It is believed that exposing preterm neonates to pain negatively affects their ability to cope with pain and stress in later childhood [15], [16].

B. Signs of discomfort

Neonates show many different responses to pain and stress. These responses can be of both physiological and behavioural nature, and can be used to detect discomfort of a neonate. Physiological responses include an increased heart and respiratory rate, increased or decreased blood pressure, decreased oxygen saturation, vagal tone and skin temperature. Behavioural responses are even more varied. Examples include vocalizations like crying and whimpering, facial expressions like grimacing with eyes squeezed shut or a stretched open mouth, and body movements like finger and toe splaying and trunk arching [15], [17]. It is worth noting that a change in any of these responses does not always imply that the neonate is experiencing stress or discomfort. Several pain-scoring

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systems (such as PIPP [18] and Comfort-NEO [19]) have been developed to aggregate the behavioural signs, providing a reliable and structured tool for pain measurement.

C. Comforting techniques

The past two decades have seen an increase in interest in neonatal pain treatment [16]. Pharmacological solutions remain popular and are the most used method for pain treatment. Non-pharmacological methods of providing comfort and pain relief do exist and some have proven to be effective. The most popular techniques include: non-nutritive sucking, offering a sweet solution, facilitated tucking and skin-to-skin care.

Non-nutritive sucking was one of the first non-pharmacological comforting techniques to be studied and refers to offering a pacifier for the neonate to suck on [20]. A sucrose solution can be provided as an extra means of comfort during more painful procedures. A syringe is used to gently squeeze some sucrose on the inside of the neonate's cheek. A pacifier is offered after the delivery of the sucrose, distracting the infant with something sweet to suck on [21].

During facilitated tucking, the caregiver holds one hand on the baby's head and another one on the feet or body, depending on what is feasible at that moment [22]. Similar techniques are containment and swaddling [23]. The aim of all these techniques is to restrict the movement space for the neonate and to maintain it in a position similar to in-utero.

One of the most successful comforting techniques is skin-to-skin care (SSC), otherwise known as kangaroo care [24]. During SSC the mother and infant are wrapped in cloth together, with the infant held to the bare chest of the mother. One downside of this comforting technique is that the neonate needs to be taken out of the incubator, which can be stressful to the child. Some neonates are unable to receive this particular kind of care, because their medical condition does not allow them to be taken out of the incubator.

Other comforting techniques include presenting the neonate with an audible heartbeat [25] or music [26] and aromatherapy [27]. If possible, breastfeeding can also be used as a non-pharmacological comforting technique, although its effect was demonstrated on term neonates [28].

The majority of these comforting techniques have in common that a parent or nurse needs to be present to provide the desired care. Although the sole presence of its parents might be comforting to a neonate, most parents are unable to be with their child continuously. The same holds for nurses, as they often have multiple neonates to care for. A comforting solution that does not require the continued presence of a parent or nurse is thus a design path worth exploring.

This paper presents a new concept for comforting preterm neonates. This concept aims at comforting preterm neonates by mimicking selected features of the baby's mother or father and making them available to the baby when the parents cannot be present themselves. The following sections will describe the concept in more detail, and discuss the implementation and evaluation of a prototype based on this concept. Finally, the implications of the proposed concept are discussed and future directions are outlined.

II. Concept

The concept for the proposed comforting solution was not based on findings from literature alone. To understand the field better user studies were performed, the NICU environment was observed and current comforting techiques were further investigated. The results of these observations are described below, followed by an explanation of the concept proposed.

A. User studies

An essential first step in the development of a new, non-pharmacological pain treatment is the recognition and evaluation of the status-quo. In User Centered Design (UCD) the end-user is constantly involved in the design process. This becomes problematic when designing solutions for neonates, simply because it is impossible to communicate with these 'users'. In this case, medical staff and parents can be valuable sources of information, in effect becoming the voice of the neonates. Interviews with medical staff and observations at a NICU facility have been performed in order to gain better insight on the conditions and treatments given at a NICU. The following paragraphs discuss these findings and their implications for the concept that is explained in detail in the last paragraph of this section.

B. NICU environment

NICU wards commonly house several incubators which are often shielded from light entering. These incubators provide a controlled environment, where amongst others temperature and moisture levels are kept at an appropriate level. The neonates constantly have their physiological signs monitored and are therefore attached to many sensors. Small bean-bag pillows are used to provide both comfort and support to neonates, and can be used by nurses to stabilize the neonates in a position that allows treatment. Small plush toys are also often present in the incubator, allowing parents to share something more personal with their child. The fact that some objects (such as the bean-bag and plush toys) are already present within an incubator gives rise to the opportunity to design a new comforting solution that can be integrated with these objects.

C. Comforting neonates

Neonates can be comforted in two ways: by providing an active comforting treatment, or by taking away sources of discomfort. Some hospitals (e.g., the Maternity District Hospital "Helena Venizelou" (GR)) have a very strict policy that focuses on the latter. The fragile neonates are taken out of the incubator only for medical treatments. The care policy focuses on limiting external stimuli to the neonates as much as possible. Noise and light levels are reduced to absolute minimum and parents can visit their babies during fixed visiting hours.

Other hospitals (e.g., MMC in Veldhoven (NL) and the Maastricht University Medical Centre (NL)) are less strict and

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emphasize on the value of parent-child bonding as a source of active comfort, therefore they allow parents to visit their baby in the NICU at any given time. These hospitals also encourage the parents to take part in their child's care, by changing diapers or bottle feeding. This kind of involvement also helps the parents who often feel that they cannot help their fragile baby during the stay at the NICU. These hospitals encourage kangaroo care as a means of comfort and bonding. Nurses and parents from these hospitals stated that infants are the most relaxed during kangaroo care.

Although it is clear that parents can play an important role in the comfort of their child, they cannot be present at all times to provide this comfort. In all hospitals, some more than others, there are situations in which alternative means of comforting are required. Therefore, it seems appropriate that a new comforting solution would focus on providing a neonate with the same feeling of comfort that parents would provide, even when the parents cannot be physically present.

D. Concept

Based on the literature review, the aforementioned user studies and a brainstorm with the design team, several concepts for a novel solution for comforting preterm neonates were proposed. After a few elimination rounds, one concept was selected. This concept, called Mimo, is a comforting solution that provides neonates with an experience similar to being held by their parents.

As already noted, neonates show less stress signs when they are in contact with their parents and held to their chest. This seems to be one of the most pleasant experiences for a preterm neonate. However, neonates cannot receive this kind of comforting at all times; parents cannot always be present at the NICU and in many occasions neonates are in a condition that does not allow them to be taken out of the incubator.

Mimo, aims at providing a comforting solution with qualities similar to those of being held to a parent's chest, available especially when the parent cannot provide the comfort him- or herself. This concept might not only increase the general comfort level, but it can also contribute to the bonding between parent and infant. Mimo gives parents the chance to record their personal features such as heartbeat, smell and temperature, which can be mediated to the child when it is in need of comfort. When the concept is fully realized, the child might experience a feeling as the parents were close to them, even when the parents are not there in a physical sense.

One of Mimo's basic characteristics is its ease of use, which enables parents to record their physiological features without guidance or in a special environment.

III. PROTOTYPE

The original concept for Mimo includes mediation of several physiological features, such as smell, heartbeat and respiration. However, building a prototype that would mediate all these features would make it more difficult to identify the most beneficial attributes of the concept. Therefore, the initial prototype of Mimo was designed to only mediate the parent's heartbeat by means of vibrations, much like a pulse.

One of the basic characteristics of the concept is that Mimo should be easy to set up and use, so that parents could record their physiological data on their own, without the guidance of a nurse for example. Then, the nurse needs only to switch on and activate Mimo when comforting is needed. Moreover, the Mimo prototype features a pillow-like device to convey the heartbeat, which can replace the regular pillows that are used in incubators, thus sustaining the neonate's environment and avoiding extra special equipment that would load the incubator. This prototype was designed to be comfortable and ergonomic for a premature neonate, but also washable and clinically safe to meet hospital standards.

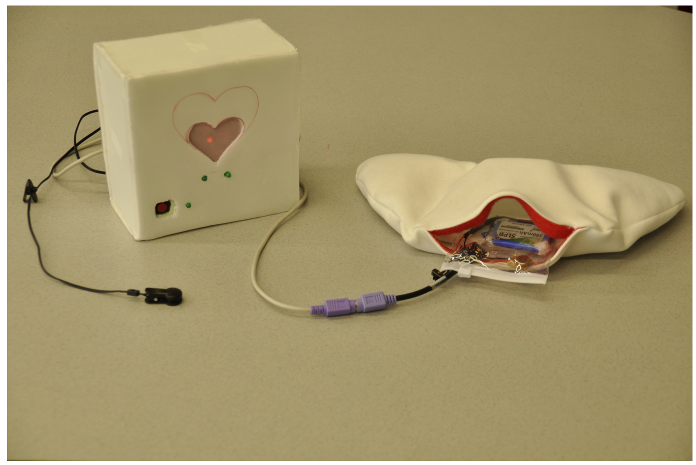

Fig. 1. Prototype with the Mimo Recorder on the left and the Mimo Pillow on the right.

The Mimo prototype (see Figure 1) consists of two distinct parts:

1) A recording unit (*Mimo Recorder*), for registration of the parent's heartbeat
2) A pillow-like object (*Mimo Pillow*), for transmitting the parent's heartbeat to the neonate

A. Mimo Recorder

The Mimo Recorder is a white, cubical box that allows parents of preterm neonates to make a recording of their heartbeat. A heartbeat sensor (photoplethysmograph), as well as a connection cable are attached to the side of the box. The front of the box features a number of LEDs displaying the status of the recording process and a button to initiate the recording process.

1) Sensor: The heartbeat sensor that is used in the prototype is a photoplethysmograph, which is an optical sensor that measures a person's pulse. An infra-red LED on one side of the sensor shines through the finger onto a photosensitive sensor at the other side of the finger. The amount of blood that flows through the finger influences the amount of light that reaches the sensor, hence providing information about the person's pulse. Although there are other ways to record a heartbeat (such as electrocardiogram sensors), the photoplethysmograph provides a quick and easy way to record a heartbeat. The ease of use of this method outweighs the slightly lower accuracy compared to other methods.

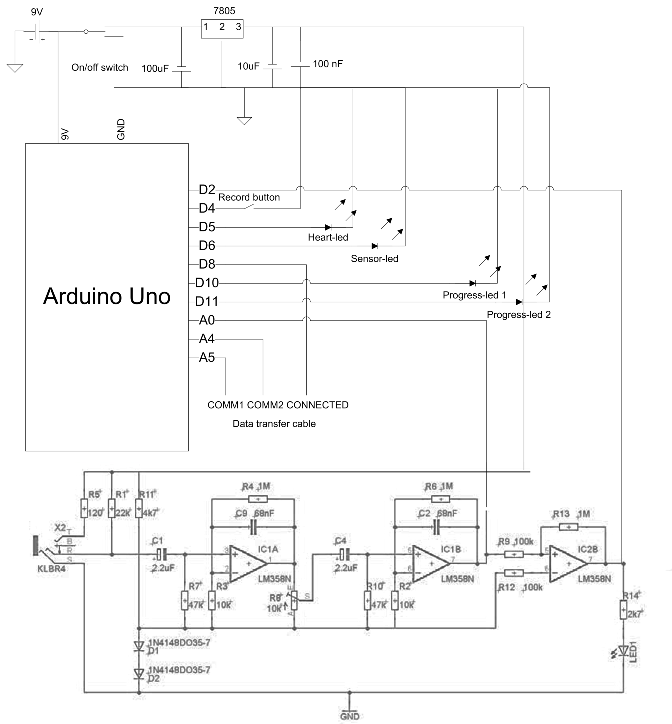

Fig. 2. Circuit diagram of the electronics in the Mimo Recorder.

2) Electronics: An overview of the circuitry inside the Mimo Recorder can be found in Figure 2. The heart of the Mimo Recorder is an Arduino Uno [29] microcomputer, powered by a 9V battery. The Arduino handles almost the complete recording process, ranging from sensing and storage to transmission of the heartbeat to the Mimo Pillow. A filter module ensures the quality of the heartbeat signal that the Arduino records. It was deliberately chosen to use a battery rather than a fixed power supply, to provide maximum flexibility to parents in their choice of a recording location.

3) User Interface: The user interface of the Mimo Recorder was designed to be as simple as possible, such that parents could perform the complete recording process themselves. Four LEDs provide feedback to the parents about the status of the heartbeat recording. One light shows whether the device is switched on, another light indicates whether the sensor is properly attached and the two remaining lights indicate whether the recording has not started yet (lights off), is currently in progress (lights blinking) or has finished (lights on). In order to record their heartbeat, parents first need to attach the sensor to their finger or earlobe. Once the sensor indicator confirms that the sensor has been properly attached, the parent can press the recording button and wait for the status lights to light steady. Then, the Mimo Pillow can be connected to the recording unit and the heartbeat will be transferred to the pillow.

B. Mimo Pillow

The Mimo Pillow is the part of the prototype that stays with the neonate. It is a boomerang-shaped pillow that is filled with polymer beads and contains a pouch that accommodates the electronics. The polymer beads that are used for the filling ensure both softness for the neonate, and stability that allows the pillow to be shaped around the neonate's body and act as support.

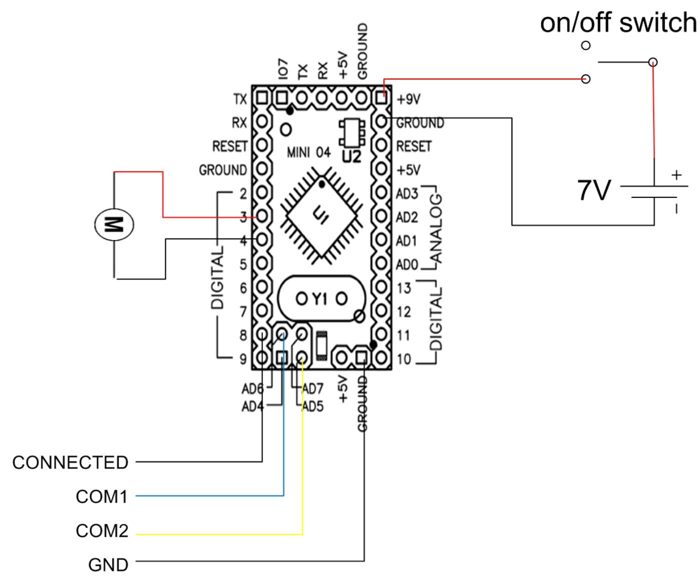

Fig. 3. Circuit diagram of the electronics in the Mimo Pillow.

1) Electronics: Much like the Mimo Recorder, the Mimo Pillow is controlled by an Arduino Mini microcomputer. This Arduino version is much smaller and flatter than the one used in the Mimo Recorder, such that it is hardly felt on the outside of the pillow. Other efforts to ensure that electronics are not felt by the neonate have been made by using a specialized flat model racing battery as power supply, a tiny vibration motor to mediate the heartbeat vibrations, and by using a tiny control to switch on or off the electronics. A detailed overview of the electronic circuit is provided in Figure 3.

2) User Interface: The heartbeat data that has been recorded with the Mimo Recorder can be transferred to the Mimo Pillow by connecting the connection cables of both devices. Once the heartbeat data has been transferred to the pillow, it is immediately ready for use. The recorded heartbeat data is stored in the microcomputer in the Mimo Pillow and is played back continuously, as long as the device is switched on.

IV. PILOT STUDY

To test the viability of the concept, a pilot study was performed with the Mimo prototype. While a pilot-study is not directly suitable for generating results on the effectiveness of the prototype, it is a good starting point to test the initial response of the neonates, nursing staff and parents to the device proposed. The study was conducted with four preterm neonates; three of them residing at the Medium Care Unit and the other one at the Neonatal Intensive Care Unit of the Máxima Medical Center in Veldhoven (NL).

A. Method

First, the heartbeats of the neonates' mothers were recorded with the Mimo Recorder. Then the pillow was presented to the neonates directly after uncomfortable procedures such as diaper changing or bathing. The pillow was presented both in a switched-on state, as well as a switched-off state. The neonates were observed before, during and after the uncomfortable procedures. Since this was a pilot study it was impossible to change the routines of the nurses present during the evaluation. This in turn caused that sometimes additional care was provided to the neonates next to the Mimo Pillow. For example, the preterm neonate who was tested in the NICU was also offered a sucrose solution in combination with the Mimo Pillow.

B. Results

1) Neonates: None of the neonates showed signs of increased stress due to the pillow's presence. In addition, some neonates showed positive responses to the pillow's presence. For example, one neonate was in severe distress after he had been bathed and was crying continuously. The crying baby was put back in the bed and the switched-on pillow was put next to him. Immediately after putting the pillow next to him, he stopped crying and showed no further signs of distress. However, when the pillow was taken away from him after a short while, he immediately started crying again. Other neonates fell asleep while lying against a pulsating Mimo pillow, further indicating that it may have a comforting effect.

2) Parents & hospital staff: Although it had not been the primary intention of the concept, it turned out that the prototype had a positive effect on the neonates' parents. During the pilot study parents made many spontaneous, positive remarks on Mimo and enjoyed the interaction with it. Hospital staff were also interested in Mimo and positive about its potential comforting effects on preterm neonates. Some of them also suggested that a full-scale study on the effectiveness of Mimo should be performed, based on the results of the pilot study.

V. Discussion

This paper presented the design, implementation and evaluation of a new, non-pharmacological comforting solution for preterm neonates. The concept (named Mimo) aims at comforting a neonate by providing it with a feeling similar to that of being close to a parent. Most neonates seem to experience a strong sense of comfort when being held by their mother or father.

The Mimo concept consists of two parts: a recording unit and a technologically enhanced pillow. The recording unit is used to record physiological data (such as heartbeat, breathing rhythm, parental smell and body temperature) from a parent. This data can then be transferred to the pillow, which includes technology that enables it to 'replay' the recorded data to the neonate. A prototype for Mimo has been designed and evaluated in a pilot study. The prototype is a limited implementation of the original concept, as it focuses only on the recording and playback of a parent's heartbeat. The pilot study performed with this prototype has shown that Mimo has no negative influence on the comfort of neonates. Furthermore, there are strong indications that Mimo might have a positive effect on the comfort of neonates.

As already mentioned before, because of the limitations that apply to a pilot study, it is difficult to make definite conclusions based on the data gathered. More neonates would be required for testing, all of whom would have to go through more trials. Also, the trials would have to be even more structured and controlled than in the current study. Due to the limitations of performing a pilot study, these issues could currently not be addressed.

Performing studies on preterm neonates is a difficult process in which it is hard to collect useful data and attribute that data to the experience the neonate is having. Much thought had gone into the evaluation plan during the design phase of this study. Due to the imposed limitations, this evaluation was stripped from many of its features. A full clinical study should include a blind evaluation of close-up video recordings of the neonates during procedures. Nurses who have experience with the ComfortNeo scale could then view video excerpts and provide scores on the comfort level of the neonate. In a future study, the physiological data of the neonates could also be logged for the purpose of statistical analysis. Such data collection was not possible during this pilot study and conclusions based on this data would also lack any statistical significance. Acquiring more accurate behavioral and physiological data for analysis of more neonates in better controlled conditions would be key to a future study.

In the current pilot study, most of the participating neonates resided in the medium care ward. Babies in the medium care ward are already much more stable than neonates staying in the NICU. This also means that these babies are exposed to less painful medical procedures, which also means they are less exposed to comforting techniques than neonates in the NICU.

Most of the trials in the current study occurred during diaper changes. The neonates that participated in this study were usually fed directly after a diaper change. It is not unreasonable to assume that neonates that remained fussy after a diaper change were actually expecting to be fed. In such a situation, the Mimo would most likely not render the desired effect.

In the current study, neonates received an artificial heartbeat reconstructed from a physiological recording of their mothers heartbeat. It can be argued that the neonate is not able to detect the difference in heart beats of different persons. Although untested, this argument is moot from the design point of view. Not only should the Mimo provide care to the neonate, it also contributes in empowering the parents during a stressful time. A random heartbeat would take this empowerment away from parents, and would not contribute to parent-child bonding

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either.

VI. Conclusion

We designed a new non-pharmacological comforting solution for premature newborn infants based on the transfer of maternal heart beat into a pillow that is equipped with a "pulsator". In a small pilot study we found that the response of the infant was positive. Finally, parents and hospital staff who interacted with Mimo during the pilot study, regarded Mimo as a very promising concept that would possibly not only comfort premature neonates, but also help parents bond with their infant. A full-scale clinical follow-up study is currently being conducted to confirm these indications.

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Designing the Parents-to-Infant Bonding Experience in the NICU

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Abstract— **This paper describes the research work on the search for design opportunities through explorative interviews within the case study 'designing the parent-to-infant bonding experience'. In the complete case study we explore how to design for support of such a complex, flexible, individualized and difficult-to-measure process as bonding. Based on a prior literature review, a theoretical design framework was constructed, focusing on experience design as the most suitable design approach. In this paper we report on a set of in-depth interviews conducted to further elucidate parents' experience of bonding during their time at the Neonatal Intensive Care Unit (NICU). These experiences are structured in the form of experience flows and used in a creative clustering session to identify design opportunities and as design inspiration. The three resulting opportunities are: (I) specific monitor design for parents as a means to get to know their child, (II) supporting a meaningful and active contribution while sitting next to the incubator and (III) supporting the acknowledgement of the difference the baby knows between parents and medical staff. Furthermore, we share the lessons learnt applying the design method of experience design to the case of parent-to-infant bonding.**

Keywords-experience design; parent-to-infant bonding; case study; disruptive design process; experience flows.

I. INTRODUCTION

Bonding between parents and babies admitted to the NICU is important for the well-being of both. In practice, the development of the bond is however hampered by factors introduced in case of a premature birth: separation, the baby's fragile health and parents having to rely on medical professionals to take care of their premature infant. In the collaboration between the department of Industrial Design at the Eindhoven University of Technology and the NICU at the Máxima Medical Center Veldhoven, one of the goals is to shift from a medical focus in the NICU, to patterns where the experiences from the user's perspective become central. The topics of bonding and comfort are of particular interest. Designing for an improved bonding experience between parents and prematurely born babies, is a typical design case involving a 'disruptive design process' [1]. The design process is disruptive due to the fact that we are designing for a goal that is ill-defined, in this case 'bonding', and the designed product/service's impact cannot be measured in a straightforward manner yet. Additionally, the user group and test environment require consideration to avoid extra stress while gathering data and introducing interventions. The NICU forms the Experiential Design Landscape for this case study [1]. In the complete case study, we explore how to design for parent-to-infant bonding and how to cope with the uncertainties in the disruptive design process: 'Which design strategies can overcome the challenges in the disruptive design process involved when designing for improved social connectedness?'. Compared to existing designs which support parent-infant bonding in the NICU in varying ways [2-5], this case study offers the opportunity to design a product/service specifically to impact bonding, starting the design process with this goal in mind. In this paper, we describe the search for the design opportunities and inspiration: how do parent experience bonding in the NICU and what kind of design intervention(s) could effectively support this?

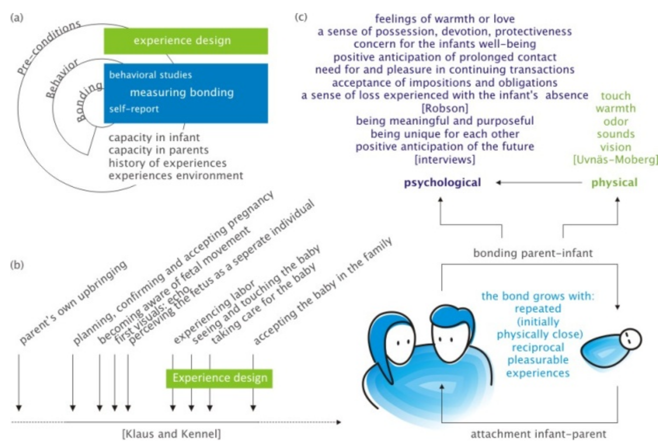

Figure 1. Theoretical Design Framework for Bonding [2].

The first step in the case study was a literature review [2] resulting in a design framework for bonding including a definition, a list of existing measurement tools for bonding, the selection of a design approach and a confined design space. In Figure 1 the design framework, which combines findings from a variety of sources [6-11] and conversations with parents in the NICU, is shown. The circular Section (a) illustrates that bonding is a 'feeling state', partially expressed in behavior, which evolves influenced by pre-conditions (such as responsiveness, privacy, stress, distance to hospital, interaction with medical staff). The timeline in Section (b) shows the time span of experiences involved. In Section (c), the two directions of bonding are shown and the physical and psychological elements involved. Summarized, bonding is defined as a feeling state of ‘love’ which “*grows with repeated (initially physically close) reciprocal pleasurable experiences*” [2]. Although the process of bonding is complex, flexible and highly individualized, the determinants essential for the bonding experience described in the definition above, appear to apply to all parent-infant dyads. Likely, some pre-conditions (such as comfort, atmosphere in the room and approachability of the baby with technology around) indirectly impact these determinants required for the experience, others more directly. We assume the following: pre-conditions -> experience -> bonding -> development infant.

Previously, we proposed to design for the ‘experience’ [12, 13] because it is not one single determinant that guarantees bonding, but it is a highly complex multi-modal combination of pre-conditions impacting the feeling over time. The pre-conditions that set the stage for the bonding experience are the things we can change and design for. Considering that bonding is affected by experiences over a life-time, we limited the design space to the period of hospital admission. The bonding experience within a defined time span and location can be more easily measured, compared to the actual level of bonding. We chose to design for the experience as perceived by the parents, which is measurable through self-report and behavioral studies.

For the design process, we previously proposed the ‘Experience Design Method’ as published by Philips [14, 15] suitable for application in the medical field. This process guides the gathering of design input and design for, or measure of the complete experience, widening the scope beyond one usability aspect, resulting in rich information. This approach can help in finding under which pre-condition the experience of bonding flourishes. The experience includes the patient’s personal view, the effect of the environment, the encounters with medical staff and the flow of experiences before and after use of the product/service. The core of experience design is the inquiring of user experience and the creation of persona/ experience flow-charts.

Based on the design framework and selected approach resulting from the first step, the second step is gathering the user’s experiences, creating experience flows and analyzing the data. In this paper, we gather the bonding experiences and distill the design opportunities, which could be expected to have a large impact on the experience of bonding. Practical outcomes, such as design guidelines are shared, as well as reflection on this phase of the design process.

II. DESIGN APPROACH

The design process (Figure 1) for the complete case study is fairly traditional (literature search, gathering user design

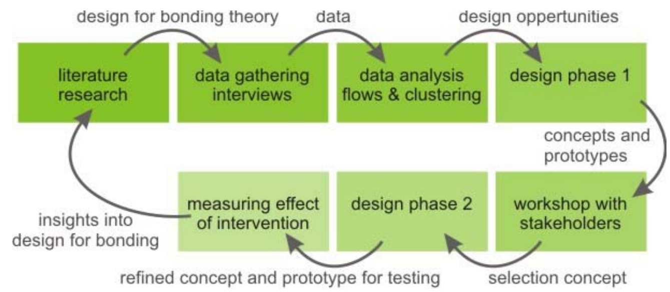

Figure 2. Schematic overview of design approach

input, design phase 1, gathering stakeholder’s feedback, design phase 2 and a validation). The choice in method for collecting user data depends on what is suitable a specific case study. As part of this case study, we chose to conduct interviews with parents about their experiences and feelings towards their infant related to the environment, while the experience is fresh in their mind. Interviews were transcribed and coded, forming the basis for the experience flows. Initially, personas based on the interviews would be created in order to design for a type of parent. However, as explained in the discussion, a creative clustering session was found to be more suitable.

A. Interview design

Five mothers (together with the fathers) were interviewed about their bonding experiences during the time their child was admitted. Three of the interviews have been held by a designer and two by a social scientist. The interviews were semi-structured, in order to give the parents room to freely introduce themes relating to bonding, and on the other hand to have topics on hand to maintain the interview flowing. In all interviews the parents were asked to describe their experience of bonding along the journey through the hospital; from giving birth, to being in the NICU/High Care for several weeks. The questions asked were about how the parents felt about the atmosphere, the interaction with the medical staff, first impressions, what they did, and how it influenced the way they felt towards their child. We asked what supported and what held them back in different stages and places. Examples of questions asked: “*How would you describe the bond with [name]?”*, “*What has strengthened the feeling of the bond?”*, “*Was there something holding you back from entering the NICU?”*, “*What was a good experience you had in the NICU?” and “Did you perform care tasks? If so, which care tasks?”*. The interviews lasted from 45 minutes to 1.5 hour and took place in the family room in the Máxima Medical Center, Veldhoven, in the Netherlands. The interviews were audio recorded, literally transcribed and names and places were replaced.

B. Participants

The parents included in the study had one or more babies admitted to the NICU or High Care department. The criteria for selecting the participants were that the baby was in stable health at the time of the interview and the parents had spend a few weeks in the NICU to be acquainted to the rhythm. In order to gain a broad picture, the parents differed in whether they were first time parents, were a single parent, stayed in the Ronald McDonalds house or their child had temporarily been transferred to a specialized hospital. The experiences of both mothers and fathers were included because the study is of an explorative, inspirational nature with a low number of participants. Four participants were native Dutch speaking and one participant was non-native English speaking. The quotes have been analyzed in their original spoken language.

C. *Experience flows*

In the experience flows, the interviews are presented with the goal of providing an overview of how the parents' feelings towards their child developed throughout the medical journey. In order to create the experience flows, distillation of factual data about places and procedures, and quotes about bonding experiences, from the transcript was necessarily. The transcripts were color coded, as in Figure 3. Factual data was marked yellow (regular black text). Literal experience quotes were marked blue (bold black text).

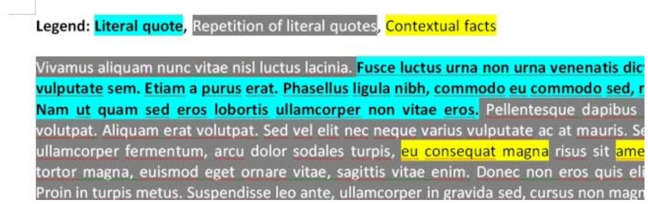

Figure 3. Coding transcripts anonymous sample.

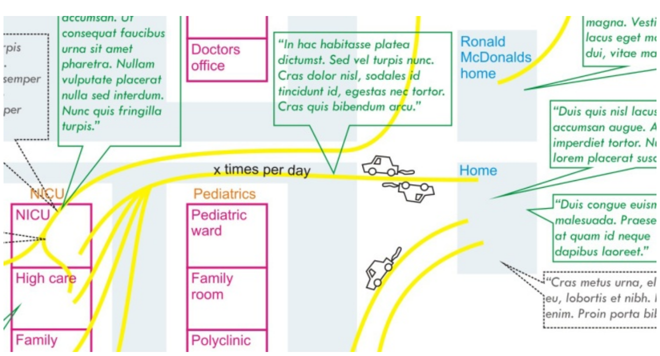

Figure 4. Experience flow anonymous sample

Parents repeated certain ideas within an interview, therefore in order to maintain the manageability of the data, the most representative quote was selected and the repetition marked in gray (regular white text). This ensured the entire transcript was considered. Since the questions were open, parts about the interviews about non-related topics were left unmarked, such as medical details about the baby or the delivery. In Figure 4 the elements for the experience flows drawn in CorelDRAW are shown. It contains the institutes, departments and rooms, with the journey as a yellow line running through. Along the journey the selected experience quotes are positioned in text balloons.

D. *Creative clustering session*

An open coding clustering session was held to start the discussion about how parents experience bonding, what the design implications are and point out design opportunities. The session was held with another designer and a computer engineer, both new to the topic of bonding, in order to gain a fresh view and stimulate creativity. In a span of a few hours the designers created clusters on post-its until all the quotes could be placed. The discussions were documented. Afterwards, the clusters were organized in more detailed clusters of which the conclusions are drawn. The five experience flows together contained too many quotes for clustering, namely 253. Therefore, the quotes most relevant to bonding feelings or activities were selected, which brought the number down to 144. The quotes were given a color specific for the interview, in order to be able to differentiate the original interviews when they were mixed in clustering.

III. RESULTS

The coding of the interviews resulted in five experience flows, with a variation of medical journeys including contextual facts, activities and feelings related to bonding.

The clustering exercise resulted in an extensive report containing conclusions for each cluster of quotes. Here the summary is presented in themes, each conclusion accompanied with one representative quote.

Separation after birth - Several mothers felt empty seeing the baby only shortly directly after birth. They wish to be with their child as soon as possible, but realize that medical care for themselves and the baby is required which they don't want to disturb. *"At the time it was just important to deliver her and connect her as quickly as possible to all contraptions", "So the period directly afterwards was a little strange. Perhaps also a little bit empty".*

NICU environment - Parents' are overwhelmed during the first impression of the NICU. They are attracted by a homely design, however feel it is not appropriate for a medical environment. *"It all went so fast and I actually can't remember it all too well", "The moment I entered I definitely noticed it is only for premature babies", "You know that he requires a lot of support and that just does not go well with a blue crib with a bell on it".*

Baby's fragile health - Parents report that in the beginning they struggle with the fear of becoming attached to the child that they might lose. For the interviewed parents this fear diminished over time as the baby's health stabilized. In time they could participate more and the baby became more responsive. *"I went through a lot of emotions, not wanting to get too attached to the child, certainly during the first week, weeks, I think. Because, well, you don't know how long he will be around", "…earlier he was connected to the CPAP* [continuous positive airway pressure]*, and then you do require some help with all these tubes. Now he is only connected to the lowflow and we can do it ourselves", "She is getting stronger and stronger. You develop a*

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stronger connection. We can do more with her, and she responds more and more.". In case of a premature birth it can be too overwhelming being confronted with the baby's fragile health. Instead of being on top of everything, parents sometimes 'chose' trust in the care provided. Or, sometimes, parents observe or participate as much as possible, thereby obtaining a sense of control. Parents react differently to live-stream of information. There is a large difference between whether the news is positive and whether the parents are in a position to act on it or not. *"I am almost more at ease while I am there, observing what is happening. Opposed to while being away and having to maintain faith",* [About witnessing the fragile moments] *"it makes you feel insecure and wonder 'Oh, will he pull through?"*, *"You record the good times on film", "therefore the videos that you have are fun to watch", "That you can see her* [on a live-stream], *that is much more intense. It makes me realize I can't be with her 24 hours a day",* [about a NICU webcam] *"So let's say maybe if I was at home, and I could see she is awake, I could rush here and maybe we could play together",* [about monitor alarms] *"You can only review the past hour or so", "but it does give you the feeling that you are updated on what happened during your absence".*

Participation in care - Mothers expressed their wish to participate in care. It strengthens their parental role. Yet with the fragile health of the baby they feel insecure, especially in the beginning. If the staff can do a nonmedical task such as changing diapers faster or better, they rather give it out of hand. *"then you actually have the feeling that there is something that you can do.* [When she is excluded, she feels] *"Less like a mother", "it is not that you can just go ahead and pick her up, and hold her to your chest. No, there is always a preceding action. You have to notify them how it is going, or ask if we can do this?".* A premature baby requires much rest, which often leaves the parent sitting next to the incubator. Parents want to actively contribute, have a reason to be there. They talk and observe, bring personal items such as a scent cloth or toy, read something, write in a journal or take a nap. *"The fact that you may not touch him, that was a bitter pill to swallow", "'Well enjoy', 'Oh', I contemplated, 'Enjoy what?', I am lying here staring at a box", "Of course there isn't all that much you can do next to the incubator. And yet there is. Having the feeling, of yes, I do love you, I am there for you. That. And I think that applies the other way around as well", "then I just look at her for a moment and continue reading. Then I do get the feeling of being there", "You really want to take the pain away from the little guy", "You feel so helpless, powerless".*

Getting to know each other - Parents learn along the way to interpret the signs of the baby, which differ from a full term baby. They use the monitoring data to get to know their child. They compare the monitoring data to their observations for confirmation. *"You can see whether he is comfortable or not. However, the first days you are not so aware of all these things. It comes naturally with Kangaroo care and caring for him. Then you just start to notice things", "Sometimes you mix it in your head", "And you do look at her, but look for confirmation in the monitor as well", "Am I right? Or do I know that already? Or am I not seeing it correctly now".* Parents are insecure about whether their child responds differently to them than to the medical staff. Three mothers mentioned that the baby recognizes them, but others strongly doubt it. Explanation about how the baby interacts and behaves supports parents. They notice that the child looks for them when hearing their voice. It motivates parents when they notice that they can calm their child. *"are you responding to me, or do you also do that when a random nurse opens the door?", "It is purely his eyes, the fact that he opens them when I am speaking to him. And I can see he does not do that with everyone. You do notice that", "I don't feel that she, when I am sitting next to her, is thinking 'Oh, that's my mother again', "It is very strange that you… although you don't know him at all. I am here twice a day, I have never had him with me for 8 hours, but these nurses, they are in his presence the entire day", "That give me something to hold onto, 'Oh, so when she does this, she may actually recognize me'", "when she does this with her eyes and they are quite capable of making a connection", "Kangaroo Care is important. If you notice that he is calming down, his breathing improves et cetera, then that feels very good. Then you really want to pull him close. It has a positive effect".* Kangaroo care physical contact is experienced as very positive. It has however limitations, such as not seeing the baby's face, not being able to smell or give a kiss. *"It is a special feeling. However you do miss lifting your child, or holding her pleasantly against your shoulder. Or… yes you hold her, but that is all", "I had him on my arm", "and thought 'wow'", "'Oh, my baby!!. Then I was studying him so intently, when I had him really right in front of me".*

Monitor system - All parents look at the monitor, but with different intensity. It is not sure whether parents always interpret the data correctly. The monitoring requires professional interpretation and does not predict the future. The sensors of the monitoring system are in first instance restraining parents from interacting, however with support of the medical staff this is overcome. The fragile health of the baby has the main impact. *"At some point, you are just sitting there* [pretending to watch the monitor] *even though your child is lying over there", "I would for example see his saturation drop, and would think: 'Oh, there he goes. How often would he do that a day, and how harmful would that be and…", "I think that I am a bit clumsy, but that is also caused by maneuvering your hands through these holes", "And in addition there are all these wires, which tend to intimidate you a bit.", "Very small. Really. Very small. So sometimes and I must be frank, when I come here and I look at my baby and then I begin to cry".*

Spending time in the NICU - Parents spend different amounts of time next to the incubator. If the parents can participate in care or perform Kangaroo care they tend to stay longer. Also when they arrive at the right moment. Planning (with the medical staff) is important. *"I reckon that I sit there each day for 6 hours watching her"*, *"Then you just lie on your bed and you can look at him. That's all fine, but after fifteen minutes or half an hour, you have seen enough"*, *"And you are aware that he mostly benefits from rest, rest and more rest"*, *"Now it easily happens that you are applying Kangaroo-care for one and a half hours. And then there is care before and after. At first you were only sitting in front of the incubator, and as a result your stay is shorter"*, "sometimes, lucky, I try to be in time", "Maybe she is then awake", *"Here you arrive at a convenient time and often his diaper has been changed already. Or sometimes you are in luck that you arrive on time and can do it together"*. For the parents days are filled with being at the NICU, traveling back and forth, pumping breast milk every 3 hours, caring for the children, house, eating, working and sleeping. A parent that spends much time at the NICU might benefit from more relaxation. Especially the days after birth, the mother needs to focus on her own recovery. Parents that spend little time, might benefit from being supported to stay longer. Some parents go home with a good feeling and are able to rest. Other parents worry and call in often. [single mom] *"I am with another child, really I try to manage the time to come here also"*, *"You are recovering from a caesarian and everyone tells you: 'Make sure you get some rest as well. Because once you have your child at home, you will also want to be a mother that can care"*, *"I am not going home with the idea of all the things that might happen. I mean, I do trust everything here"*, [recommended by a nurse] *"It is so pleasant. Just being at home with your child and husband…. I don't have to go to my child, because I know he is in the right place"*, *"If you call, you are again afraid of what they might say. You would almost consider not to call. But then you cannot sleep, so that does not work either"*, *"It was also not pleasant when I was not around, when I was at home. I felt guilty and wanted to be there"*, *"I think of her every day, every minute, every hour"*

Trust in care provided - Staying updated is of main concern to the parents. Parents notice the difference in communication styles between hospitals when they are (temporarily) transferred. If the communication is inadequate, parents can start to worry at home. Relying on the care provided is sometimes difficult. Most parents put their faith into it or say they simply have to and meanwhile keep a close eye on things. "I should know what is going on with my daughter", *"Every time that you're there, they would approach you and tell you about things that have happened and how he was doing"*, *"You would spot a note and then you would think: 'Hey, this says something about morphine'. That was not exactly shared with me, so in turn you would ask 'Did he receive morphine', and only then they would explain"*, *"Yes, and when I would lay in bed at night I would think 'Yes it went well today', but yes, did it really go as well as they said it did?"*, *"Would they be doing something with him?"*, [about a nurse of which the mother feels she does not know her child well enough] *"If I wouldn't be here now, you would consider this as normal"*, *"Here they are the experience experts really, here are the people who know about what could happen to your child"*.

IV. Discussion

The interviews showed the complexity of how the feeling of bonding develops over time, and the highly intertwined processes affecting parents in an individualized way. Parents expressed contrasting thoughts about needs, e.g., that some parents would want to see their child live via a webcam at home, and others would find it confronting to be faced with the fact that they are away from the child at that moment. These contractions, also within individuals, result in a fine line to walk when designing an intervention. The interviews also show that pre-conditions affect each other: when e.g. the mother has comfort, the baby relaxes in turn, resulting in higher responsiveness when the baby is in an alert awake state. The design opportunities are therefore tied closely together; as soon as a concept emerges, it is easy to imagine how another opportunity is affected as well. It is unpredictable which pre-conditions will have the largest impact on the experience of bonding, because it is such a complex individualized process. The proposed opportunities therefore are not a guarantee, and user tests with prototypes are required in order to gain insight into the actual effect of the intervention.

A. *Design oppertunities*

We identified the following design opportunities:

1. Health info is being used to get to know the baby: do parents interpret correctly?
2. Parents sitting next to the incubator wanting to contribute while the baby needs to rest.
3. During Kangaroo care not being able to really see or interact as parents would 'normally' do.
4. Helping parents to feeling more secure about the baby's ability to distinguish between parent and medical staff.
5. Health info; the balance between wanting to know everything all the time, and resting with peace of mind.
6. Planning and being 'in luck' of arriving at the right moment for care tasks or interaction.
7. Care info: wanting to know everything that was done with baby. Trust in care while away.
8. Recording the good moments to re-live at home.
9. Wanting to see and be with the baby right after birth.

The three design directions selected as the most promising to proceed the design phase 1 with are (I) 'specific monitor design for parents as a means to get to know their child', (II) 'supporting a meaningful and active contribution while sitting next to the incubator' and (III) 'supporting the acknowledgement of the difference the baby knows between parents and medical'. These three opportunities are well represented in the interviews and are

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likely to affect the experience early on, right from hospital admission. Furthermore, they aim for 'co-located' bonding, which has not been addressed much previously.

B. *Design guidelines for bonding experience*

Based on the literature research, the experience flows and clustering sessions, the following design guidelines were formulized:

1. The intervention must positively affect the experience of bonding under which the bond between parents and infants grows: *"Repeated (initially physically close) reciprocal pleasurable experiences"*.
2. The intervention may not obtrusive; parents must have the option to use (certain functions within) the intervention. (a) The amount of information the parents receive about their child's health status must be adjustable according to their personal needs. (b) The privacy settings must be adjustable to the parent' personal needs with privacy ensured in all settings.
3. The intervention may not restrict the parent' autonomy, but rather support a higher level of autonomy.
4. The intervention must be safe.
5. The intervention may not introduce opportunities that negatively affect bonding, such as stimulating the parents spending less time at the NICU with their child.
6. The intervention may not relay on intensive instruction or support by the medical staff, unless it is saving time by optimizing time consuming in another tasks.
7. The intervention may not cause any discomfort for the baby, which conflicts with the goal of improving the developmental outcome by reducing stress.
8. The intervention may not stimulate the parents to wake the baby or provide stress when he or she needs to rest.
9. It is preferable that the parent' focus is pointed towards the baby than away.
10. It is preferable that the intervention stimulates natural interaction between parent and child.

C. *Benefits and challenges of experience design*

Conducting interviews while the parents are in the middle of the experience, resulted in spontaneous reactions. We noticed that the topic of bonding had not been considered extensively yet by the parents, because health had been of their main concern. The downside introducing the heavy topic is that it resulted in emotionally intensive interviews. It faced parents with the undesired situation. Nurses reported that it lingered with parents, even days after. Asking the parents in a later stage likely causes less stress, however probably provides more socially desired answers.

At first the goal was to create personas in order to design for a certain 'type' of parent. However, five interviews were too few in order to build stereotypes. Although in the clustering session indeed certain ideas were repeated, 'sets' of these responses did not repeat in the five interviews.

The ordering of the data in the form of experience flows in this case study did not result in additional insights. Perhaps the scope was too large. We do expect that the rich experience flows will be useful later on for concept scenarios. Once the concepts are there, it is interesting to imagine how the intervention would impact the experience flows and in which stage. Would these parents use the proposed concepts in different ways? The experience flows contain the complete story with personal insights in an organized way, opposed to the generalized clustered data.

CONCLUSION AND FUTURE WORK

The bonding process between parents and prematurely born babies is important for the well-being of both, however in practice the process is hampered due to separation, fragile health of the baby and parents having to rely on the care by medical professionals. Designing for the support of bonding experience, raises questions about the definition of bonding, how bonding can be effectively supported through design and how to measure the impact of such an intervention. In the complete case study 'designing for the parent-to-infant bonding experience' we explore how to design for such a complex, flexible, individualized process. In this paper we describe the search for inspiring design opportunities that are expected to impact the bonding experience, through conducting in-depth interviews about bonding experiences of parents with a premature baby admitted to the NICU. Five interviews resulted in five experience flows and thematic conclusions derived from a creative clustering session. The interviews illustrate the complexity of how the feeling of bonding develops over time, and the highly intertwined processes affecting parents in an individualized way. We identify three design opportunities and a set of design guidelines, which form the inspiration and focus for the design process. We conclude that user experience tests with prototypes are required in order to gain insight into the actual effect of the intervention(s).

The design case is continued with the development of concepts and prototypes. The goal is to create one functional prototype of which the effect of the intervention on the bonding experience can be measured.

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A Case Study of a Practical Use of "MusiCuddle" that is a Music Therapy System for Patients with Dementia

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***Abstract*—In this paper, we conducted an experiment that an operator presented tunes using the "MusiCuddle" system to a patient with dementia who repeats utterances. MusiCuddle converted the patients' utterances into pitches (F0) at a predetermined interval. In response to an operator's simple key entry, the system automatically played tunes based on those pitches. This function may contribute to resonating with the patient's emotions on the basis of iso-principle that is one of principle of music therapy. In an experiment, we segmented a patient's utterances into sentences and compared her utterances when music was presented and was not presented. The results of the analysis showed that the sentences were uttered with music tended to include the word of the immediately previous sentence, as if she stutter out them. We thought that if a patient's attention could be captured by tunes, MusiCuddle could contribute to alleviating their symptoms.**

***Keywords**-*Music; Convert utterances into pitch.*

I. INTRODUCTION

Dementia is the deterioration of cognitive ability and skills due to an organic disorder (such as Alzheimer's disease, dementia with Lewy bodies, cerebral vascular dementia, and frontotemporal dementia, and so on.).

As one of the symptoms of dementia, some patients repeat stereotypical behaviors and utterances. When we recorded the utterances of patients with mental instability for one month, regardless of whether a result of a test of cognitive function is good or bad, many patients repeated stereotypical utterances [1]. One of them repeated, "Did you do it?" in a falsetto, another cried, "I want to go to the restroom!" even after she had been to the restroom. Another locked herself in a restroom and repeated the same words in a loud voice all day. However, when a caregiver said something to her, she could greet clearly.

In most cases, we could not understand what the patients were saying. Although doctors, nurses, and caregivers talked to the patients and attempted to distract them into another action, it was not easy to calm the patients down. Therefore, music that resonates with the patients' emotions and calm their symptoms can be expected to help the caregivers in caring for these patients.

Music therapy is one of the methods known to alleviate symptoms of dementia. Park and Pringle Specht [2] conducted an experiment in which individuals with dementia listened to their preferred music. The result showed that mean agitation levels were significantly lower while listening to music than before listening to the music. Svansdottir and Snaedal [3] showed a significant reduction in activity disturbances, aggressiveness, and anxiety in the group assigned music therapy. The study of Nair, Heim, Krishnan, D'Este, Marley, and Attia [4] did not find that ambient Baroque music had any calming effect. However, they showed that in order to achieve the desired behavioral effect, music may need to be tailored rather than generalized.

The iso-principle [5], which is one of the principles of music therapy, suggests that a music therapist first perform music that matches the current mood of a patient. This type of therapy is also effective for symptoms of mental instability in which patients repeat stereotypical behaviors and utterances, such as in some dementia patients.

Therefore, we [1] present a music therapy system, "MusiCuddle," which accompanies patients' agitated repetitive stereotypical utterances with music that resonates with his/her mood. This system converts the patients' utterances into pitches (F0) at a predetermined interval. Then, the system presents a music phrase (tune). The first note of it is same as the pitch converted from the patient's utterances. Moreover, one type of tune is cadence that begin on a chord that resonates with the patient's current emotions and finish on a terminative chord that calms his symptoms.

In this paper, we prepare more tunes in the database of MusiCuddle. Then, we conduct an experiment that one of authors presents tunes using MusiCuddle to a patient with dementia who repeats utterances.

II. Resonate with the patients' emotions

The iso-principle is well known to music therapists trained in the United States [6]. "Iso" simply means "equal"; that is, that the mood or the tempo of the music in the beginning must be in "iso" relation with the mood or tempo of the mental patient. The principle extends to volume and rhythm [5]. The actual use of music in a particular therapeutic situation depends upon the particular needs of the individual, such as a need for therapy to change behaviors on an immediate basis to relieve troubling conditions [7]. For example, if the client is distressed or agitated, then the quality of the music initially should match his or her mood and energy. By adopting the iso-principle, the first choice of music may be familiar and energetic [8]. In improvised music with the client's music, "match" means that the therapist's music is not identical to the client's music, but is the same in style and quality [9]. Likewise, in "validation," one of the methods used for communication between clients and therapists, a therapist will observe the mood of a client and will emit the same tone with his voice to indicate that he sympathizes with the patient [10].

In our ongoing research, we are constructing a music therapy system that performs music semi-automatically. It is difficult for the system to play improvised music that resonates with the patient's emotion in the same way as a music therapist. However, we have tried to construct the system using an advantage point of a computer. In the first step of our research, we allowed the system to convert a patient's utterances into pitches (F0) continuously. In response to an operator's key entry, the system selects a short phrase in a database. The first note of the phrase is same as the pitch converted from the patient's utterances. We expect that this function may contribute to resonating with the patient's emotions on the iso-principle. Moreover, we prepared cadences that begin on a chord that resonates with the patint's agitated mood in the database of MusiCuddle.

III. Set up system

MusiCuddle is a music therapy system that performs music when an operator (e.g., a caregiver) pushes any of the keys of the electronic keyboard or a button on the display of the system [1]. The system also continuously converts the patient's utterances into pitches (F0). In response to the operator's key entry, the system determines a pitch at a predetermined interval. The system selects a tune, a short phrase, in the database on the basis of that converted pitch. The top note of the tune is the same as the pitch converted from the patient's utterances. To convert the patient's utterances into pitches, we employ a pitch extractor to convert the utterance into one pitch (i.e., Do, Re, Mi). This is based on the technique for conversion of sounds that have unstable pitches and unclear periods, such as natural ambient sounds and the human voice, into musical notes [11].

In the original system shown by [11], if the operator gave a start trigger, the system would initiate the processing to obtain the F0 (fundamental frequency) time series from the acoustical signals (i.e., a singing voice), which were being recorded via the microphone. The short-term F0 estimation by Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT) for the power spectral is repeated until the system catches an end trigger from the operator (i.e., the caregiver). The system then calculates a histogram of pitches with the F0 time series between the start and end triggers. Finally, only the most frequent pitch is selected and is output as the pitch of the period.

For our research, some processing designs were modified. Figure 1 shows the processing of the system. Considering the attitude of the operator, we would assume that the triggers would be input after the operator catches the utterance of the patient. Therefore, we omitted the start trigger. The system starts a short-term F0 estimation just after invocation of the system and continues it thereafter. When the operator inputs a trigger that is regarded as an end trigger, the system calculates a representative pitch for a predetermined period just before the trigger based on the above-mentioned method. Then the system plays a prepared MIDI (Musical Instrument Digital Interface) sequence that corresponds to the representative pitch. These modifications of our system improve usability by reducing the time lag between the input of the trigger and the output of phrase.

To extract the F0 against the mixed acoustical signal of the patient's utterance and the cadence output from the speaker, our system needed two of the same microphone (the better solution is one stereo microphone) and one speaker. The microphones are set in front of the speaker to record the speaker's sound at the same level from both microphones. On the other hand, both microphones are displaced against the patient to record the levels of the patient's utterance that are clearly different. The system calculates the differential signals from the signals of both microphones to cancel the sounds of the MIDI sequence where they are localized in the center position. The F0 estimation is then determined with these differential signals.

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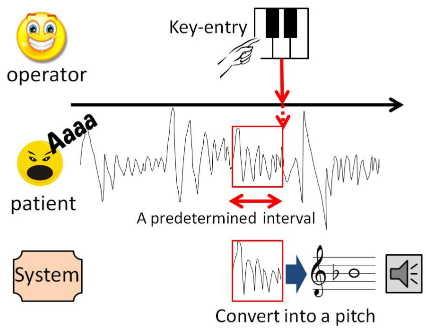

Figure 1. Convert into a pitch.

IV. Database of Tunes

Tentatively, we prepared four types of phrases in the database. Table I shows some details of the phrases. The patients who repeat utterances in many cases are experiencing irritable moods and high anxiety. Generally, dissonance chords indicate tension and consonance chords indicate relaxation. Clinically, a combination of these chords can elicit tension and relaxation within the human body. Therefore, we prepared dissonance chords and consonance chords. Moreover, we prepared cadences that begin with dissonance chords and finish with consonance, as well as terminative chord.

“Four chords” means that the same four chords are presented in one phrase (see Fig. 2). The chord is composed of two notes. Thirty-seven MIDI files, of which the top notes of the chords are C3∼C6, were prepared per one type chord (see Fig. 3). Accordingly, the system can select a MIDI file of which the top note of the chord is the same as the pitch converted from a patient’s utterances. There are 888 MIDI files (phrase files) for a four-chord type phrase. In the “Rhythm” column of Table I, “Quarter note” means each of the four chords is presented in the rhythm at the rate of 60 times per minute. “Random” is unregulated rhythm [12]. The “Interval” column shows intervals between two notes composed of each chord. In the “Change of volume” column, “No change” means four chords are presented in the same volume. “Crescendo” means that the volume of notes gradually increases one by one, while “Decrescendo” means that the volume of notes gradually decreases.

In the type of “Cadence,” we prepared 96 kinds of cadences that begin with dissonance chords and finish with consonance, as well as terminative chord. These cadences were picked out from two piano suites; “Das Wohltemperierte Klavier Band 1, BWV846-869,” composed by J. S. Bach in 1722, and “24 Preludes and Fugues, Op.87,” composed by D. D. Shostakovich in 1952. Both suites consist of 24 pieces (24 tonalities), and one piece consists of a prelude and fugue. We could prepare at least 96 cadences, if two cadences were chosen from one piece, the prelude, and the fugue. The top note of the first chord in each cadence is applied as any of 12 tones, Do, Do sharp, Re, Re sharp, and so on. Moreover, each piece is translated to go up/down one to three octaves to cover all possible tones converted from the patient’s utterance. The plural cadences correspond to each of 12 tones converted from the patient’s utterance.

In the other direction, we prepared phrases from Japanese school songs. Ashida reported that reminiscence-focused music therapy might reduce depressive symptoms in elderly people with dementia [13]. Therefore, we picked out short phrases from some familiar songs for elderly people. We created a simple accompaniment for each phrase. Each phrase was arranged into 37 MIDI files, the first notes of which were C3∼C6.

Fig. 4 shows two kinds of phrase. These are the same tune, “Akaikutsu.” The top of them begins with C4 as well as the bottom of them begins with G#4. The difference in the pitch of the first notes affects and changes the entire mood of the music.

The last type phrases were created from the patient’s utterance. All segments of her utterance could be converted into some notes. Fig. 5 shows an example. Previously, her utterance, “i-ma-se-n-de-su-yo [I am not here],” was converted into a phrase “re-re-re-si-ra-ra-si.” This phrase was also arranged into 37 MIDI files, the first notes of which were C3∼C6.

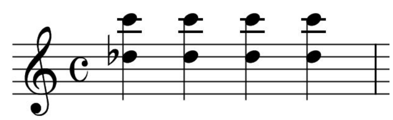

Figure 2. Same four chords are presented in one phrase.

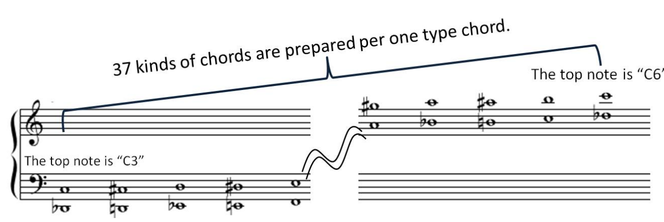

Figure 3. The top notes of the chords are C3-C6.

V. Experiment

A. Ethical Considerations

This experiment was approved by the Research Ethics Board of Saga University. The participant of the experiment,

Table I
TUNES

Types	Details	
Four chords	Rhythm	Quarter note, Eighth note, Sixteenth note, Random
	Interval	Perfect prime, Perfect fifth, Major seventh
	Change of volume	No change, *Crescendo*, *Decrescendo*
Cadence	Bach	Das Wohltemperierte Klavier Band 1, BWV846-869
	Shostakovich	24 Preludes and Fugues, Op.87
Japanese school song	“Yuki,” “Akaikutsu,” “Hana,” “Tsukinosabaku,” etc	
Stereotypical utterance	*Ex.* Utterance, “i-ma-se-n-de-su-yo” is converted into a phrase “re-re-re-si-ra-ra-si.”	
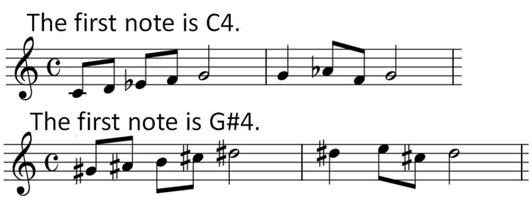
Figure 4. The difference of the first note changes the entire mood of music.

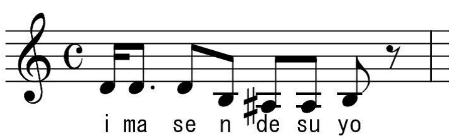

Figure 5. The segment of patient’s utterance is converted into some notes.

who is a patient with dementia, her husband, and the hospital director were informed about intention of the experiment and the treatment of personal information. Moreover, they were informed that they could withdraw from the experiment at any time. Then, we obtained written consents from them.

B. Participant

The participant is a patient with frontotemporal dementia (FTD) staying in a hospital. She is 72 years old. The score of Revised Hasegawa’s dementia scale (HDS-R[14]) was 17 two years ago. She repeats the same words for many hours a day. When she is agitated, she locks herself in a restroom. However, she is lucid enough to remember the nurse’s name and greet her clearly.

C. Preliminary experiment

When the participant was agitated and repeated the same sentences, one of the authors repeated sentences in accord with the participant’s repetition in the same melody and rhythm. Fig. 6 shows these sentences in music score. Sentence A means the participant’s sentence. First, the author tried to repeat the same sentence as the participant’s together. Namely, both of them repeated Sentence A, “i-ma-se-n-yo.” Second, the author tried to repeat a different sentence using the same melody and rhythm pattern as the participant’s together. Namely, the author repeated Sentence B, “go-han-de-su-yo” although the participant was repeating Sentence A.

In the first trial, the participant turned around to pay attention to the author. However, she kept repeating the same sentence harmonised with the author’s repeating. In the second trial, the participant changed the sentence A to the author’s sentence, “go-han-de-su-yo” in the same melody and rhythm.
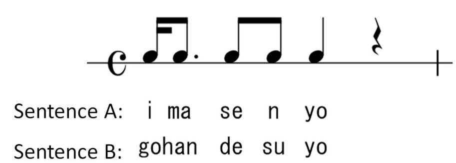
Figure 6. Author repeated sentences in accord with the participant’s repetition.

D. Method

When the participant is agitated and repeats the same words, an operator (one of authors) presents tunes using the system MusiCuddle. The tune is presented through a wireless cuboidal speaker, 123×36×35mm, and the patient’s utterances are recorded through a wireless columnar microphone, about 75mm in height and 24mm in diameter. These devices are set in the restroom.

E. Analysis method

In this paper, we analyze the participant’s utterances in three records: 16, 8, and 3 minutes. The participant’s utterances are segmented into small sentences based on the way of repeating. Then, we analyze ways to change the sentences.

First, we determine whether each sentence was uttered "with music" or "without music." If a tune was presented in the middle of a sentence, the sentence was considered to be uttered without music. In this case, the sentence was started to utter before presenting the tune. So, we consider that the sentence was untouched by music. In the following example, "hirugohandeha" is recognized as no music:

P: imasendesu **hirugohandeha** imasendesu

[

(Start a tune)

In the following example, "ima" as well as "gohanden" are recognized as they were uttered with music:

P: imasendesu ... imasen **ima gohanden**

[ ]

(Stop a tune)

The sentence, "ima" was started to utter with music. So, this sentence was affected by the tune. Moreover, we consider that "gohanden" was affected by the tune because this sentence was started to utter immediately after presenting the tune.

Second, we determine whether each sentence includes the words that are part of the immediately previous sentence. In the following example, "imasendesu" includes the immediately previous sentence "ima:"

P: ima imasendesu

F. Results

1) Presented tunes: In the first and second record, we presented the tunes arbitrarily by giving triggers to MusiCuddle. In the third record, we did not present the tune at all. Recording time is 27 minutes. The total time of presenting tunes was 6 minutes and 54 seconds, which is one-fourth of all recording time.

Table II shows kinds of tunes, times of the tune, and total time of the tunes at the first and second-record. First, we presented six four chords. In this record, we use one type of four chords: Major seventh, Quarter note, and No volume change. This chord can show unsteady images to the participant. Next, we presented a Japanese school song, "Yuki," four times. The patient sang only the last phrase, "zun zun tsumoru [accumulate rapidly]" along with the melody the first time. Continuously, "Akaikutsu" was presented five times. Next, five cadences were presented. The kind of cadences were decided by the pitch converted from her utterances. After that, we again presented "Yuki." She sang again. The last tune of the first record was a Japanese school song, "Hana." In the second record, first, we presented a Japanese school song, "Tsukinosabaku," four times. Continuously, "Yuki" was presented nine times. However, she did not song along with them. Next, we presented the phrase created from her utterance "i-ma-sen-de-su-yo" five times. At the end of the record, we presented "Hana" two times.

2) Classify utterances: The participant uttered all times of the experiment. Most of utterances were rhythmical and fit into same meter, although she uttered many kinds of sentences. Fig. 7 describes some examples of her sentences. One of the authors took rhythm dectation of these sentences. These example shows even if the sentences are different, they fit into four-four time.

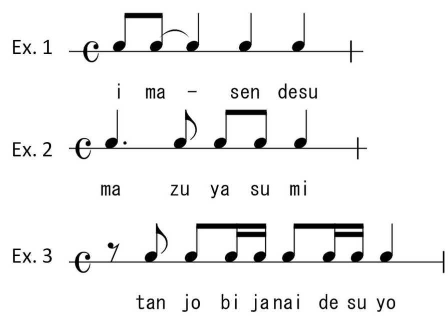

Figure 7. Sentences fit into four-four time.

Table III shows the kinds of sentences. The segmented sentences are 680 (84 kinds) in 27 minutes. There were many cases in which the contents of the sentences are almost the same even if the words among the sentences vary slightly.

Table IV shows the comparison between "with music" and "without music." The number of changing sentences is 114 with music and 179 without music. The tune-presented time is one-fourth of all recording time. Therefore, the change of sentences with music occurs with greater frequency than that without music. However, with music, the rate that the sentence includes the word of the immediately previous sentence is higher than that without music. The rate with music is 82.5%, whereas that without music is 41.3%.

Table IV
THE NUMBER OF CHANGING SENTENCES.

	with music	without music
changing sentence (ALL)	114	179
include the words of the immediately previous sentence.	94	74
rate (%)	82.5	41.3

VI. DISCUSSION

Patients with dementia who continually repeat utterances tend to repeat the same or similar content. Moreover, the

Table II
PRESENTED TUNES IN THE EXPERIMENT.

Types	Tunes	Time(sec.)	Number of times	Beginning note	Total time(sec.)
Four chords	Major seventh & Quarter note & No volume change	3	6	D3(2),D#3,F3,A3,C4	18
Cadence	No.22 Fugue (B)	8	1	C4	8
	No.1 Fugue (B)	8	1	F3	8
	No.15 Fugue (B)	11	1	F#3	11
	No.22 Prelude (S)	15	1	D4	15
	No.3 Fugue (S)	25	1	F#3	25
Japanese school song	"Yuki"	9	21	D#3, E3(3),F3(7),G3(2),G#3,A3(3),A#3,B3,C4,D4	189
	"Akaikutsu"	10	5	D3,F3,F#3,G#3,A#3	50
	"Hana"	8	4	D3,G#3,A#3,G#4	32
	"Tsukinosabaku"	11	4	F#3,F3, C4,C3	44
Stereotypical utterance	i-ma-se-n-de-su-yo	3	5	G3,G#3,A3(2),A#3	15
Sum	–	–	50	–	414

In the "Tunes" column, "(B)" means the tune is a part of a piece composed by Bach, and "(S)" means the tune is a part of a piece composed by Shostakovich.
In the "Beginning note" column, C, D, E∼A, and B show Do, Re, Mi∼Ra, and Si. A4 is about 440Hz. Values in parentheses shows the time of each beginning note.

participant in our experiment uttered in the same meter, four-four time (see Fig. 7). Once patients fall into the pattern of repeating utterances, it is difficult for them end the cycle independently. Generally, their caregivers address the patients directly by calling out to them in attempt to shift their attention, but it is not easy.

MusiCuddle might resonate with his or her mood in accordance with the iso-principle. The first notes of the tunes that were presented in the experiment were also varied and wide-ranging because the pitches (F0) converted from the participant's utterances were varied and wide-ranging. The difference in the pitch of the first notes affects and changes the entire mood of the music (see Fig. 4). Tonality and pitch (high or low) are essential determinants of musical mood.

The results of our case study suggest that tunes presented by MusiCuddle may give patients an opportunity to stop repeating utterances. The participant in our case study stuttered when each tune was presented. Each tune presented by MusiCuddle began with a note in the same pitch as that of the participant's utterances. However, each melody presented by MusiCuddle was different from the pattern of the participant's utterances. On the other hand, in the preliminary experiment, when one of the authors repeated the same sentence as the participant's sentence using the same melody and rhythm pattern, the participant kept repeating the same sentence although she was paying attention to the author (see Sec. V-C).

These results suggest that the sounds that are presented to patients should neither be identical to nor entirely different from their utterances. The patients might attend to the tunes according to their similarity in pitch, and deflect attention away from repeating utterances if the melody is too strikingly different from their utterances.

VII. CONCLUSION

In this paper, we used a support system called "MusiCuddle" to present short music phrases to a patient with dementia. In our experiment, MusiCuddle presented a tune that began in the same note as a converted note from the participant's utterances. We then analyzed the changes in her utterances. When the tune was presented, she stuttered and tended to begin saying a new sentence that only contained a part of the immediately previous sentence. These results suggest that MusiCuddle may give the patients the opportunity to escape the pattern of repeating utterances.

We did a case study on only one participant to examine the effectiveness of MusiCuddle. Although we simply say "dementia" when referring to individuals who have deteriorating cognitive abilities, individual expression and progression of symptoms can very significantly from person to person. We have to consider the condition of participants and the advice of their primary doctors when we examine the participants. Thus, we will accumulate case studies of several participants step by step.

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Table III
SENTENCES SEGMENTED FROM THE PARTICIPANT'S UTTERANCES IN THE EXPERIMENT.

Estimated meaning	Sentences
I am (not) here.	imasu (1), imasendesu (201), imasen (48), imasende (43), ima (5), deimasendesu (1), sokoniimasen (1), imasenyo (1), uruchiimasendesu (1), ryugaimasende(1)
It is (not) luch time.	mazugohandesu (78), mazugohan (14), mazugohande (6), hirugohannarimasendesu (5) gohandesu (4), hirugohandashimasendesu (2), hirugohannarimasende (2), gohandashimasendesu (2) haisugugohandashimasendesu (2), mazugohandesuyo (2), gohan (2), gohanden (1), gohannarimasendesu (1) gohannaidesuyo (1), hirugohande (1), gohandashimasende (1), gohanninarimasu (1) gokaimenogohandashimasendesu (1), mawarinogohangoyamoyashisendesu (1)
First,	mazu (34), mazuyasumi (33), mazudesu (32), ma (6), mazuya (3), mazudesu (2), mazude (1), mazugo (1), mazuyasu (1)
Not do	masende (10), masendesu (6), masendesuyo (2)
Bath time, Break	ofurohaittadesuyo (2), ofuro (1), ofurojaimasende (1), hitoyasumi (1)
(Not) Birth day	tanjobijanaidesu (3), tanjokainaidesuyo (3), tanjobijanaidesu (1), tanjobijaimasendesuyo (1) tanjobijaarimasendesu (1), tanjobijaarimasendesuyo (1)
Time	1ji40fundesuyo (13), yoruninarimasendesu (9), 1jihandesuyo (8), 3jihanninarimasendesu (8), yoruninarimasendesuyo (5) handesuyo (4), 3jihandesuyo (4), 1jihande (3), 2jihandesuyo (2), 3jininarimasendesuyo (2), 1jihandesune (1) 1ji10fundesune (1), 1ji (1), 1jihandesuyo (1), 3jihanni (1), 3jihanninarimasendesuyo (1), mou3jininarimasendesu (1)
Snack time	oyatudesuyo (1), oyatujaimasendesu (1), keikihanaidesuyo (1), keikihanaidemasendesu (1), keikihanaitodesu (1)
Soon	suguha (1), suguhanaidesu (1)
"Yuki"	zunzuntumoru (2)
Question	imashitaka (1)
Greeting	konnichiha (1)
Others	dojoninarimasende (1), ugoninarimasende (1), sonouchimasende (1), mashi (1), bokujaarigatoarigato (1), basyohanaidesuyo (1)

Values in parentheses shows the time of each sentence.

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Olfactory Stimulation in Premature Neonates: The Relevance of Early Experience

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***Abstract* – While in the womb, a fetus experiences olfactory stimulation by means of the surrounding amniotic fluid. This prepares the fetus's olfactory system to its postnatal life. If a child is born prematurely, it is deprived of this preparation because it is hospitalized in an incubator in the Neonatal Intensive Care Unit. This sudden transformation from the womb to an overly stimulating hospital environment imposes increased stress to the vulnerable neonates. This paper discusses various studies that show the importance of early olfactory stimulation, an approach to improving olfactory stimulation and protection, and suggests examples of implementing these improvements in future research and design.**

Keywords –NICU; early experience; odors; stress; olfaction.

I. INTRODUCTION

Of the total amount of childbirths about 11% (USA) is born premature [1]. Recent advancements in neonatal care have ensured that these prematurely born infants have an ever rising survivability rate [2]. Despite these advancements, prematurely born infants are prone to develop long term problems due to exposure to stressful environmental stimuli (light, noise, smells, etc.) [3].

Most of these prematurely born infants will, immediately after childbirth, be placed in an incubator at hospital's Neonatal Intensive Care Unit (NICU). Over the years extensive research about the impact of premature childbirth has shown that these children, and their parents, go through quite a stressful period [4][5]. Because of the premature exposure to a postnatal environment, external stimuli are perceived as extra stressful and painful by prematurely born babies compared to their full term counterparts [6].

In order to support during their stay in the NICU various innovations have been devised. Among these innovations are for instance a sound system for the NICU [7], the Babybloom incubator [8], the sound awareness system SoundEar [9], the Smart Jacket [10], and the remote cuddling FamilyArizing system [11] are all developed with the intention to improve the NICU experience for parents and their children.

We concluded, however, that none of these interventions consider the olfactory development and environmental impact on prematurely born infants.

Through this paper, we provide not only a review of relevant literature, but we also draw attention to the importance of early exposure to odors in prematurely born infants. We want to highlight the importance of both protecting neonates from stressful environmental odors as well as providing them with comforting parental odors in the NICU. Finally, we formulate various challenges future research might face.

II. OLFACTORY DEVELOPMENT

During fetal growth the first nasal tissue can be observed during week 7 or 8 of pregnancy [12]. The swallowing reflex is detectible from week 12 onwards and around 18 weeks gestational age nonnutritive sucking begins. Around the same time (week 17) the fetus is capable of tasting. Smelling however only starts in around gestational week 24 [13]. Coordinated sucking and swallowing are perceivable from gestational week 35 to 40 [13], the end of the final trimester. This means that the sense of smell is fully functional in prematurely born neonates in the NICU (24> weeks of gestational age).

In humans, the receptors for the olfactory system are located high in the nasal chambers in the epithelium in the nasopharynx or nasal cavity. These receptors are not only stimulated during inhalation (orthonasal route), but also when infants suck or when children and adults swallow (retronasal route) [13].

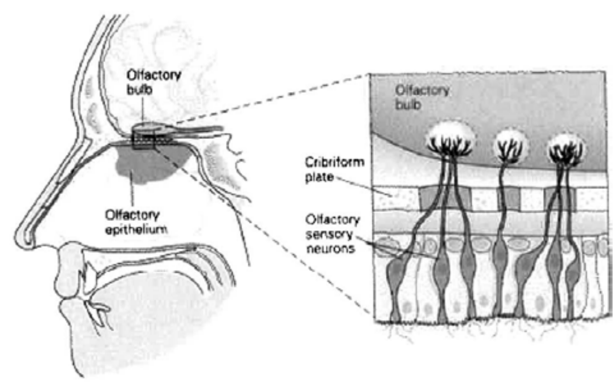

Figure 1. Nasal cavity [12].

From the nasal cavity olfactory neurons go through the cribriform plate to the olfactory bulb. Positioned directly underneath the prefrontal cortex, the olfactory bulb

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transmits its signals to the olfactory cortex, which is located in the brain's limbic system [12]. The pathways that go through the thalamus back to the orbitofrontal cortex are thought to be responsible for the perception and discrimination of odors [12]. Furthermore, olfactory information is communicated from the amygdala to the hypothalamus and to the hippocampus. These are thought to mediate the emotional and motivational elements of odor and many of the physiologic and behavior effects of scents [12].

III. STRENGTH OF MATERNAL ODOURS

Already in the womb neonates are fully capable of detecting and discriminating odors/flavors through their olfactory system starting at 24 weeks gestational age [13]. During the third trimester the child's olfactory system is preparing for the future world it will live in by tasting parts of its mother's diet through the amniotic fluid [14]. Extremely prematurely born neonates are deprived of this experience and are instead presented with new unfamiliar environmental odors inside the NICU. Various researches have shown, however, that prematurely born infants prefer maternal odors over these new environmental odors.

In their study, Schaal et al. [15] showed, for instance, that prematurely born infants are capable of distinguishing their mother's body and breast milk odor from other mother's odor samples. A test by Russel et al. [16] showed that mothers show similar capabilities of recognizing their own baby. Furthermore research concludes that babies show positive head turning and appetitive mouthing if presented with flavors which were part of their mother's diet during pregnancy [17][18]. This shows that during pregnancy the fetus already tastes and smells their mother's diet, providing them an initial preference immediately after birth [19]. Similar tests show that babies calm down faster after smelling maternal breast milk [20].

Furthermore it has been shown show that neonates have less apnea without bradycardia and less apnea with severe bradycardia if presented with a pleasant odor [21]. In addition it is demonstrated that neonates cry less during separation from their parents if presented with amniotic fluid odor [14].

Concerning non-maternal odors in the use of pain relief, Goubet et al. [22] introduced vanillin to premature neonates. They have shown that infants showed less crying if presented with this familiar odor. Some aromas seem to distract infants from slightly painful stimuli. However, they are not distracting enough for more painful procedures [23].

During our literature study, we were surprised to find no literature concerning design or procedural interventions for communicating paternal odors to prematurely born infants. Although the effects in literature are quite promising, as far as we know, nobody has tried to specifically develop systems or products that provide the possibility of communicating paternal odors to the child. Nowadays, the only practice that enables odor communication in the NICU is the use of odor cloths. Worn by mothers, these pieces of fabric are left next to the child in the incubator to provide a more comfortable incubator experience. However, these cloths need to be washed often and don't provide any indication if they still contain maternal odors or not.

Due to the observation of this gap in research and development within the NICU, we identify a new research niche. In this paper, we present our vision of how to approach the development and implementation of paternal odor communication in the NICU.

IV. APPROACH

Traditionally the means of relieving stress and pain in neonatal patients was to provide them with anesthetics and/or sedatives. In recent years, research has shown that there are other means of providing pain and stress relief in prematurely born neonates. In this section, we would like to take the opportunity to propose an overview of the overall approach in neonatal environmental stress relief.

The main approach in the NICU, in order to reduce environmental stress relief, is the reduction of environmental stimuli. We like to refer to this as "phase 1" in the overall process. In order to achieve this we observed redesigns of the NICU architecture (e.g., single patient rooms), its apparatuses (e.g., incubator), providing the neonate with protection (e.g., goggles for neonate) and educating both medical practitioners and parents (e.g., the NIDCAP program).

The main goal of these interventions is to ensure that stressful environmental stimuli are reduced to, what we like to call, the "no-stress-line" (see Figure 2). This no-stress-line depicts the pivot point where all stressful environmental stimuli no longer have a stressful effect on the neonate.

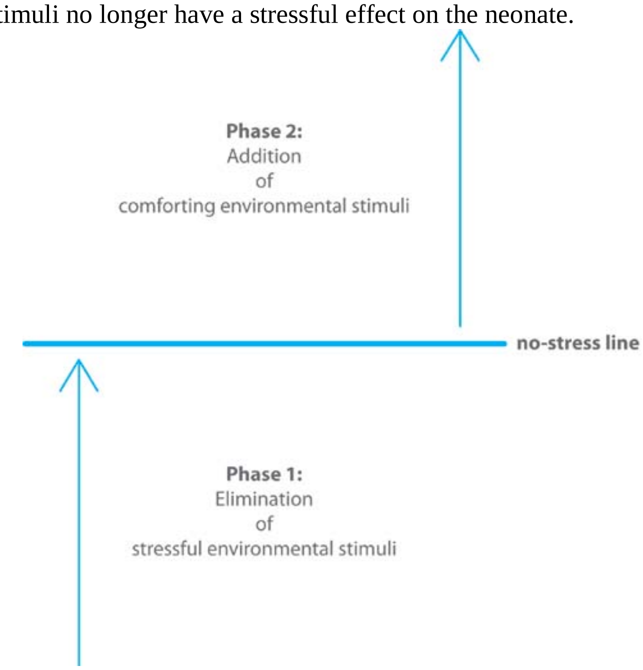

Figure 2. Approach diagram.

From the no-stress-line onward we come to what we like to call “phase 2”. This area depicts environmental stimuli that provide the neonate with comforting environmental stimuli. Although the child might not experience stress, the addition of comforting environmental stimuli in phase 2 ensures a rise in the quality of the NICU experience for neonates.

Overall, we see in presented studies that such interventions have a favorable influence on neonates in the NICU.

For instance, the sound system developed by Panagiotidis and Lahav [7] is specifically designed for the NICU to communicate maternal sounds inside the incubator. Resulting tests with the system have shown that the presentation of maternal heartbeat and voice produce short term improvements on the physiological stability of preterm babies [24] . Furthermore, Doheny et al. [25] showed a reduced frequency in apnea and bradycardia in premature neonates through the presentation of the same maternal sounds in the NICU.

Concerning the implementation of comforting stimuli into the NICU, we like to place phase 1 chronologically prior to phase 2. If stressful environmental stimuli are not removed, there is no need for implementing comforting stimuli in phase 2. This is because, usually, the comforting stimuli have to be presented in such quantities that they themselves become stressful environmental stimuli.

In the following sections of this paper, we present how we envision the implementation of the here mentioned approach on the early olfactory experience of neonates.

V. Clinical Implications

We are convinced that a number of measures could be taken to improve the early olfactory experience of premature infants. The first step would have to be to identify stressful environmental olfactory stimulants in the vicinity of premature neonates. Although no conclusive study has been found, detergent and adhesive remover are proposed as unpleasant odors to premature neonates [26]. In order to provide a more concrete answer on which environmental odors are stressful for neonates, we believe more dedicated research is needed.

First, research should determine which of the odors in the vicinity of neonates are classified as stressful for the neonate. Secondly it should be investigated how frequent a neonate is, in general, exposed to these odors. The logical next step would be to eliminate the exposure of these stressful odors to the child. This can be done by means of providing the child with protection to the odors or looking for ways to remove or replace odorous chemicals.

In phase 2, the child should be presented with comforting environmental (paternal) odors, odors that have shown their favorable influence on premature neonates.

Here, we like to propose various suggestions about what we believe are viable implementations in order to improve early olfactory experience for prematurely born infants in the NICU.

VI. Phase 1

First, we would like to highlight opportunities that are expected to provide less frequent experience of stress.

A. *Identification of Stressful Odours*

Before the protection of prematurely born infants to stressful environmental odors can start, the odors should first be identified. A survey of 99 neonatal units in France resulted in nine groups of products with a total of 76 distinct commercial preparations [27].

Overall, depending on their respiratory support, preterm neonates were on average exposed 1320-1800 times to chemical unpleasant odors during their first month of life of neonatal care [27].

Bartocci et al. [26] described a method of measuring the impact of odors on prematurely born neonates by means of near-infrared spectroscopy. In their study, they describe that the presentation of a pleasant odor (vanillin) ensures an increase in blood flow in the orbitofrontal cortex, while the presentation of a unpleasant odor (detergent and adhesive remover) ensures a decrease of blood flow in the orbitofrontal cortex [26].

B. *Removal of /protection against stressful odours*

The moment when odors are classified as stressful to premature neonates, it is time to consider means of removing them or providing protection against them.

First of all, it should be considered if odorous materials and chemicals could be replaced with less obtrusive alternatives.

Another means to reduce the exposure of stressful environmental odors to neonates could be changing staff behavior. For instance, it has been shown that by means of using ethanol-based hand disinfection, medical practitioners can ensure a high variable concentration of ethanol vapors in incubators [28]. Although one might search for non-ethanol based disinfectant, it is also plausible to ensure that medical practitioners ensure a longer evaporation time between the application of disinfectant and manipulations in the incubators [28].

By reconsidering behaviors of both parents and medical practitioners, the exposure to stressful odors might be diminished as well.

VII. Phase 2

Sequential to Phase 1, it is important to proceed into Phase 2; during this phase comfortable stimuli are made available to the child in the NICU.

A. *Support Kangaroo Care*

Kangaroo Care (KC) is a well implemented method in the NICU [29][30]. During KC, the neonate is placed onto one of the parent’s naked chest in a supine position. During

KC the parent's body provides the child with warmth, protection and familiar odors. Especially when the child is on the mother's chest, the child is able to smell familiar odors from the mother's chest and nipples.

This early presentation of familiar odors is expected to be an important factor in the child-parent bonding [31].

B. Introduce maternal odors in the NICU

Earlier in this article, we showed the importance of maternal odor presentation to prematurely born infants in the incubator. Until the current time however no specifically designed apparatus could be found that is capable of providing maternal odors to prematurely born infants. We believe it would be highly beneficial to develop such a scent dispenser for the NICU in order to provide neonates with maternal odors.

C. Early food experience

In their 2011 article Lipchock et al. [13] describe the importance of early exposure to food related odors and tastes for the quality of food learning in neonates. As a fetus the child would be exposed to elements of the maternal diet through swallowing the amniotic fluid. As a premature neonate, this experience is mostly lost.

It has been established that the cultural appreciation of food starts well before consuming solid foods [13]. This corresponds with research performed by Marlier et al. [19], who show that a fetus already learns to appreciate tastes of their amniotic fluid in the womb as a preparation for foods outside the womb. Since prematurely born infants are usually tube fed, the taste of their food (usually maternal breast milk) is taken away from them.

Besides learning, a child might have of early food experiences, smelling and tasting food in itself also provides pleasure [12].

VIII. CHALLENGES IN ODOR RESEARCH IN THE NICU

During our process of thinking about and working on odor designs for the NICU, we came across various obstacles that we believe should be taken into account for future designs and development.

A. Odor library

First of all, there is the point where one odor is not the same for everybody. Since the olfactory bulb is closely positioned to the prefrontal cortex it is known that memories and odors are strongly connected [32].

As adults, we already have an extended "library of odors" at our disposal. We already have an immense amount of experiences with various odors. This helps us to interpret new odors better and ensures that odors are already linked to certain experiences. For prematurely born babies, this library is virtually empty.

Research both by Schleidt and Genzel [33] and Delaunay-El Allam et al. [34], for instance, showed that newly born babies are able to learn new scents and couple them to the positive experience of being close to their mother. This means that there might also be a risk of connecting new odors to negative experiences. This risk that should be taken seriously.

B. Human body odours

The second major obstacle that researchers are likely to face while developing new odor communication designs for the NICU is the fact that you likely have to work with human odors. Human odors are as unique as a person's fingerprint and are, therefore, close to impossible to replicate artificially [35]. Furthermore, people go through cycles during which the content of their odors [36] and their perception of odors changes [32]. For instance, the menstrual cycle of a woman determines the odor strength and type of a woman [37]. This together with our diets [38] ensures that our personal odor varies over time. This all makes it quite difficult pinpoint which variables impact the experience of people if presented with human body odors.

C. Anxiety odours

Finally, there is the point where even maternal odors could ensure stress in neonates. Various researches show that human sweat is capable of communicating anxiety among humans [39][40][41][42]. Because the NICU is quite a stressful environment for parents as well, researchers run the risk of capturing and communicating anxiety related odors from the parents to the child. Unfortunately, no research could be found that further supports this hypothesis specifically in the NICU.

IX. CONCLUSION AND FUTURE WORK

While in the womb, a fetus experiences a specific olfactory and gustatory stimulation. However, if prematurely born, infants are deprived of this experience and are exposed to a highly stimulating environment of, among others, lights, sounds and odors. Therefore, the long hospitalization of prematurely born infants in the NICU is likely to have adverse effects on the long term development of these neonates. An extensive bundle of research suggests that the presentation of maternal/paternal odors to prematurely born infants has a positive effect on both the stress reduction as well as comforting of babies in the NICU. However, both in literature and in practice, hardly any interventions can be found which implement these insights on olfactory stimulation. We believe that as a first step for implementation, emphasis should be put on the removal of stressful odors (Phase 1) and sequentially implementation of comforting odors (Phase 2) in the NICU. The implementation of these comforting will probably encounter various obstacles. Since the child has a virtually empty "odor library", researchers run the risk of teaching babies new scents and coupling them to negative experiences. Furthermore, since we are talking mainly about human body odors, there is still a large portion of research need on the capturing and preservation of these odors. We

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believe that it is possible to design and develop systems that will overcome these obstacles and provide better care to neonates and their parents in the NICU.

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Application of Structural Equation Modeling for Inferring Toxicity-Dependent Regulation in Human Embryonic Stem Cells

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***Abstract*—Chemical toxicity threat our daily health, especially for embryos. Reveling toxicity-dependant regulation in human embryo is one of the effective approaches to prevent some chemical effects. In previous study, we developed a network inference approach, based on Structural Equation Modeling (SEM). In this study, we improved the SEM approach and applied this enhanced approach to expression profiles in human embryonic stem cells exposed to various chemicals. The inferred gene regulatory models among neurodevelopment related genes clarify the differences between chemicals, and the network shapes reflected the features of chemical toxicities. The effects of Acrylamide toxicity finally aggregated to a neuronal cell-related gene, even though Diethylnitrosamine disturbed normal cell differentiation-related genes. Furthermore, gene regulatory network with Thalidomide was complicated, but embryonic development-related genes were estimated as the finally effected genes by Thalidomide toxicity.**

Keywords-Structural Equation Modeling; Embryonic Stem Cell; Gene Regulatory Network; Chemical Toxicity.

I. INTRODUCTION

We are exposed to many chemicals in our daily life, and chemical toxicity is known to exert harmful effects on human health. Actually, some diseases are caused by exposure to environmental pollution [1][2], including chemicals such as methylmercury [3][4], and so on. Furthermore, some chemical toxins are threatening, since they can cause abnormal cell differentiation in embryos [5][6][7]. Clarifying the details of the toxic stress response in embryonic cells is crucial for the prevention of harmful chemical effects [8][9].

To gain a better understanding of the role of the toxic stress response, a gene regulatory network is useful. With the gene expression information, the regulatory networks among the genes can be inferred. Various algorithms, including Boolean and Bayesian networks, have been developed to infer complex functional gene networks [10][11]. In our former investigation, we developed an approach based on graphical Gaussian modeling (GGM). The GGM approach is combined with hierarchical clustering for calculations with massive amounts of gene expression data, and we can infer the huge network among all of the genes by this approach [12][13]. However, GGM infers only the undirected graph, whereas the Boolean and Bayesian models infer the directed graph, which shows causality.

Recently, we developed a new statistical approach, based on Structural Equation Modeling (SEM) in combination with factor analysis and a four-step procedure [14]. This approach allowed us to reconstruct a model of transcriptional regulation that involves protein-DNA interactions, from only the gene expression data. Furthermore, SEM approach allows us to strictly evaluate the inferred model by using fitting scores. The SEM approach is available for the detection of causality among selected genes, as the linear relationships between genes are assumed to minimize the difference between the fitted model covariance matrix and the calculated sample covariance matrix [15][16][17].

Here, we applied the SEM approach to the limited expression data of neurodevelopment related genes in human embryonic stem cells exposed to various chemicals. The chemicals were considered to be toxic and to adversely affect the neurodevelopment related genes. Thus, inferring the gene regulatory network among neurodevelopment related genes will help to elucidate the toxic stress response in the human embryo. Since the regulatory interactions among the genes were unclear, a new approach for assuming an initial model should be developed for the application of SEM. In this study, we used an improved SEM approach that includes a new method for constructing a preliminary initial model, in the absence of known regulatory interactions. The resulting gene expression data clarified the chemical-specific interactions among the neurodevelopment related genes.

II. MATERIAL AND METHODS

A. *Expression data*

We were provided the expression data which were measured in previous investigation [6], and the details of data are follows. The nine genes considered to be affected by chemicals were measured in the human embryonic stem cells: GATA2, Lmx1A, MAP2, Nanog, Nestin, Nodal, Oct3/4, Pax6 and Tuj1 [6][18]. As an internal control, the expression of beta-actin was also measured. The expression data were obtained from human embryonic stem cells exposed to 15 chemicals [6][18]. The toxicity of each chemical was classified into one of three types: Neurotoxic, Carcinogenic and others. The human embryonic cells were exposed to each chemical for several time periods: 24 hours, 48 hours, 72 hours and 96 hours. Each chemical was also tested at 5 concentrations: very low, low, middle, high and very high. The expression of the selected genes was measured twice under each condition by RT-PCR, and thus 300 expression patterns per gene were measured [18].

The measured expression level of each gene was normalized as follows:

$$E_g = \frac{1}{N}\sum_{i=1}^{N}\log_2\left(\frac{e_g^i}{e_{bActin}^i}\right) \tag{1}$$

Here, N is the number of repeated experiments, e_g^i is the measured expression level of gene g under one set of conditions, and e_{bActin}^i is the beta-actin expression level measured under the same conditions. The expression level of each gene was divided by that of beta-actin, for intracellular normalization. To minimize the experimental error, the logarithms of the normalized expression data were obtained and averaged.

B. Extraction of causalities from expression data

For the iteration of model fitting in SEM, an initial model should be assumed from known information. To construct the initial model among the 9 neurodevelopment genes from the time series expressions, we applied cross correlation to the expression profiles measured for each chemical and each concentration.

Cross correlation is utilized as a measure of similarity between two waves in signal processing by a time-lag application, and it is also applicable to pattern recognition [19]. The cross correlation values range between -1 and +1. In a time series analysis, the cross correlation between two time series describes the normalized cross covariance function. Let $X_t = \{x_1, \cdots, x_N\}$, $Y_t = \{y_1, \cdots, y_N\}$ represent two time series data including N time points, and then the cross correlation is given by

$$r_{xy} = \frac{\sum_{t=1}^{N}\{x_t - \bar{x}\}\{y_{t+d} - \bar{y}\}}{\sqrt{\sum_{t=1}^{N}\{x_t - \bar{x}\}^2}\sqrt{\sum_{t=1}^{N}\{y_{t+d} - \bar{y}\}^2}} \tag{2}$$

where d is the time-lag between variables X and Y. In this case, the expression profiles were measured at 4 time points, and thus three cross correlations of each gene pair were calculated with $d = -1, 0, 1$.

C. Construction of the initial model

In this study, we focused on the chemical-specific regulatory network, and thus the differences between times and concentrations could be merged for the construction of the initial model. Figure 1 shows the new method developed for constructing an initial model of each chemical, with the merging of several conditions. The time difference was summarized by the cross correlations among genes. The time lag, which was defined for the calculation of the cross correlation, was used for the extraction of causality between all gene pairs. According to the time lags, three cross correlations were calculated between each gene pair, and we compared them with the absolute values of the cross correlations. The value d, with the highest cross correlation, was selected as the causal information between the gene pairs, and a matrix composed of the selected ds was constructed as the time lag matrix of each chemical at one concentration. Thus, five time lag matrices were constructed for each chemical (Fig. 1a).

To obtain the chemical-specific interactions among genes, we extracted the binomial relationships between gene pairs from the five constructed time lag matrices for each chemical (Fig. 1b). From the binomial relationships, we constructed a frequency matrix for each chemical, composed of the frequencies of all gene pairs (Fig. 1c). In this step, the difference in the concentration is merged as the frequency in the matrix. We extracted the gene pairs with frequency matrix values greater than or equal to two, as the chemical-specific regulation (Fig. 1d). From the extracted relationships between the genes, we reconstructed an initial model for each chemical (Fig. 1e). These initial models included the time series information as the directions of edges, and the different concentrations of each chemical were summarized as the existence of edges in the model.

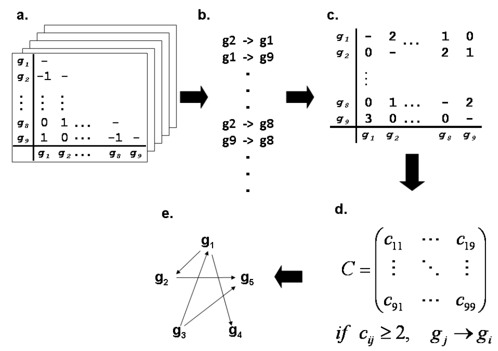


Figure 1. Developed procedure for initial model construction.

The procedure for constructing an initial model from the time-lag information of the cross correlation coefficients. (a) Time-lag matrices for each chemical. In this study, three time-lags were selected for the calculation of the cross correlation coefficients. Thus, three cross correlation coefficient values were obtained between all gene pairs. The time-lag value with the highest absolute value among the cross correlation coefficients was selected. Time-lag matrices were constructed for each concentration, so five time-lag matrices were obtained for each chemical. (b) Binomial relationships. These relationships were extracted from the five time-lag matrices. If the same relationships exist in several concentration matrices, then the extracted binomial relationships are duplicated in this step. (c) Frequency matrix of causal relationships between all gene pairs. From the binomial relationship, we can count the frequency of relationships between gene pairs. (d) Selection of possible causal relationships from the frequency matrix. The possible relationships between genes are considered to persist at several chemical concentrations. Thus, we selected the relationships with two or more values in the frequency matrix. (e) Construction of an initial model with selected causal relationships. By this approach, an initial model can include cyclic structures.

D. Structural Equation Modeling without Latent Variables (SEM without LV)

In general, SEM is a comprehensive statistical model that includes two types of variables: observed and latent. These variables constitute the structural models that consider the relationships between the latent variables and the measurement models that consider the relationships between the observed variables and the latent variables. These relationships can be presented both algebraically, as a system of equations, and graphically, as path diagrams.

In this study, the selected genes (GATA2, Lmx1A, MAP2, Nanog, Nestin, Nodal, Oct3/4, Pax6 and Tuj1), which are related to neurogenesis, were defined as the observed variables. Meanwhile, none were defined as latent variables. All observed variables were categorized into one of two types of variables, exogenous and endogenous, according to their interactions with other variables. Exogenous variables are those that are not regulated by the other variables, and endogenous variables are regulated by the others. In the initial model, the starting genes are defined as exogenous variables, while all other genes are defined as endogenous variables. Regulatory relationships exist between the observed variables in the network models. The model is defined as follows:

$$y = \Lambda y + \varepsilon \tag{3}$$

Here, y is a vector of p observed variables (measured gene expression patterns), and Λ is a $p \times p$ matrix representing the regulatory relationships between the observed variables. Errors that affect the observed endogenous variables are denoted by ε . The SEM software package SPSS AMOS 17.0 (IBM, USA) was used to fit the model to the data.

E. Parameter Estimation

Parameter estimation was performed by comparing the actual covariance matrix, calculated from the measured data, and the estimated covariance matrices of the constructed model. Maximum likelihood is commonly used as a fitting function to estimate SEM parameters:

$$F_{ML}(S, \Sigma(\theta)) = \log|\Sigma(\theta)| - \log|S| + tr(\Sigma(\theta)^{-1} S) - p \tag{4}$$

Here, $\Sigma(\theta)$ is the estimated covariance matrix, S is the sample covariance matrix, $|\Sigma|$ is the determinant of matrix Σ , $tr(\Sigma)$ is the trace of matrix Σ , and p is the number of observed variables. The principal objective of SEM is to minimize $F_{ML}(S, \Sigma(\theta))$, which is the objective function and is used to obtain the maximum likelihood. Generally, $F_{ML}(S, \Sigma(\theta))$ is a nonlinear function. Therefore, iterative optimization is required to minimize $F_{ML}(S, \Sigma(\theta))$ and to find the solutions [20].

F. Iteration for Optimal Model

The regulatory network analysis by SEM consists of two parts: parameter fitting and structure fitting. After the parameters of the constructed model are estimated by maximum likelihood, the network structures are evaluated according to the goodness of fit between the constructed model and the measured data. Through acceptance or rejection of the models, the optimal model that describes measured data can be selected.

In the network model, the covariance matrix between variables is calculated by the estimated parameters. The similarity between a constructed model and the actual relationships is predicted by comparing the matrix calculated from the network model to the matrix calculated from the actual data. To detect quantitative similarity between a constructed model and an actual relationship, fitting scores were developed. In this study, the quality of the fit was predicted by four different fitting scores: GFI, AGFI, CFI and RMSEA. Values of GFI, AGFI and CFI above 0.90 are required for a good model fit. RMSEA is one of the most popular parsimony indexes displayed in the table, and RMSEA values below 0.05 represent a good model fit [21]. Furthermore, RMSEA values of 0.10 or more are considered to indicate that the constructed model is far from the actual data.

To optimize the model, an iteration algorithm was developed, as follows:

Step1: Deletion of a non-significant edge from the model. Use 0.05 as the significance level for the determination of the chemical-specific interactions among genes. The output of SEM programs includes the probability of each edge, and thus we deleted the edge with the highest probability.

Step2: Reconstruction of the network model. The structure of the network model without the non-significant edge is different from the former network model. Thus, all parameters should be re-calculated from the reconstructed model, and the similarity of the network structure is also re-calculated.

Step3: Iteration of Steps 1 and 2 until all edges become significant. Since the probabilities of all of the edges in the reconstructed models have also changed, the deletion of the non-significant edges is executed step-by-step.

Step4: Addition of a possible causal edge to the reconstructed model. According to the Modification Index (MI), we add a new causal edge between the observed variables. The MI value indicates the possibility of new causality between the variables, and thus we add a new edge according to the highest MI score.

Step5: Iteration from Steps 1 to 3. By the addition of a new edge to a constructed model, the structure of network model is changed again. In other words, all parameters, including the probabilities of all edges, have also changed again. Thus, we execute the iteration from Step 1 to Step 3 again.

Step6: Determination of significant relationships among error terms. After all of the edges are significant and all of the MI scores are lower than 10.0 in the constructed model, significant relationships between error terms are estimated by the MI scores. The relationships among the error terms have no direction, and thus they are a correlation between error terms. These relationships were used for the calculations, but were not incorporated into the network.

III. RESULTS AND DISCUSSION

A. The chemical concentrations have no effect

In this study, gene expression was measured in the presence of various chemicals, with several exposure times and at different concentrations. To reveal the most effective factor for gene expression, ANOVA and Tukey's HSD test were applied to the measured data. In statistics, ANOVA is utilized to detect differences between groups in terms of some variables. Since the chance of committing a type I error will be increased by performing multiple two-sample t-tests, a statistical test is needed to determine whether or not the means of more than two groups should be applied. The use of Tukey's HSD test clarified which means are significantly different from one another. Interestingly, the groups that were classified by the concentration of chemicals showed no significant difference in their gene expressions. Thus, the concentration of chemicals had no effect on the expression of the tested genes in the ES cells.

The numbers of significantly expressed genes between each chemical pair are shown in Table 1. From this table, the differences in the gene expression were not significant among the same type of toxic chemicals. Furthermore, the toxicity difference between neurotoxic and carcinogenic did not cause an expression difference for almost all of the genes. However, the exposure to 'other' chemicals, such as Thalidomide, bisphenol A and Permethrin, caused significant expression changes in many genes. To reveal the differences in gene expression due to the type of chemical toxicity, we selected one chemical, which was the most different from those of the other toxicity types, as the representative chemical for each toxicity type.

TABLE I. NUMBER OF GENES WITH SINIFICANTLY DIFFERENT EXPRESSION

		Methylmercury	2-Nitropropane	Acrylamide	p-Nitroaniline	4-hydoroxy PCB107	Benzo[a] pyrene	Diethylnitrosamine	Diethylaminofluorene	Phenobarbital	Tamoxifen	Diethylbestrol	TCDD	Thalidomide	Bisphenol-A	Permethrin
Neurotoxicity	Methylmercury	-														
	2-Nitropropane	1	-													
	Acrylamide	0	4	-												
	p-Nitroaniline	1	2	1	-											
	4-hydoroxy PCB107	2	4	0	0	-										
Carcinogenic	Benzo[a] pyrene	4	5	1	2	0	-									
	Diethylnitrosamine	4	3	5	4	5	5	-								
	Diethylaminofluorene	3	3	4	5	5	7	0	-							
	Phenobarbital	3	2	4	0	1	2	6	6	-						
	Tamoxifen	3	4	3	1	0	0	6	6	0	-					
	Diethylbestrol	3	5	2	0	1	0	5	6	0	0	-				
	TCDD	3	2	1	0	0	1	5	6	0	0	0	-			
others	Thalidomide	5	7	5	5	5	4	7	7	4	4	4	5	-		
	Bisphenol-A	5	6	5	5	3	4	6	7	6	3	3	3	0	-	
	Permethrin	4	6	4	5	4	4	7	7	3	4	4	4	0	0	-
		Neurotoxicity					Carcinogenic							others		

Expression profiles were compared between all chemical pairs for each gene by Turkey's HSD test, and the genes that were estimated as exhibiting significantly different expression dependent on chemicals were counted.

The toxicities of the 15 chemicals were divided into 3 categories, Neural, Carcinogenic and others. Thus, three chemicals, Acrylamide, Diethylnitrosamine and Thalidomide, were selected as the representative toxic chemicals for neural, carcinogenic and others, respectively.

B. Genes are hierarchically controlled by chemical toxicity

We utilized the new method to construct the initial gene regulatory network models under the conditions with the three chemicals. Even though the new method can detect the cyclic interactions among genes, such as feed-back regulation, the structures of the constructed initial models indicated the hierarchical regulations among the genes. Figure 2 shows the constructed initial network models. The initial models of Acrylamide, Diethylnitrosamine and Thalidomide were composed of 9 genes with 19 relationships, 8 genes with 14 relationships, and 8 genes with 10 relationships, respectively.

There are some obvious features in the hierarchical diagram of each initial model. The numbers of exogenous and endogenous genes are different from each other. The initial Acrylamide model was composed of 4 genes as exogenous genes, but only Oct3/4 was the last endogenous gene. Thus, the expression profiles of Acrylamide indicated the quick responses of many genes after the chemical exposure, and only one gene was affected later. In contrast, Thalidomide exposure induced the expression of only one gene. These differences between the initial chemical models summarized the distinctive gene expression profiles for each chemical.

All of the initial models included some duplicated gene interactions, such as a direct interaction between two genes and an indirect interaction between them. To simplify these duplicated interactions, we only retained the longest path between two genes, since the regulation displayed by a direct path could be replaced by indirect paths in the model. In the initial model, the edges do not represent the direct regulation, but the preceding information. Thus, the difference between direct interaction and indirect interaction in the initial model is not very important. By retaining the longest paths, all of the preceding information was included, as the simplest diagram.

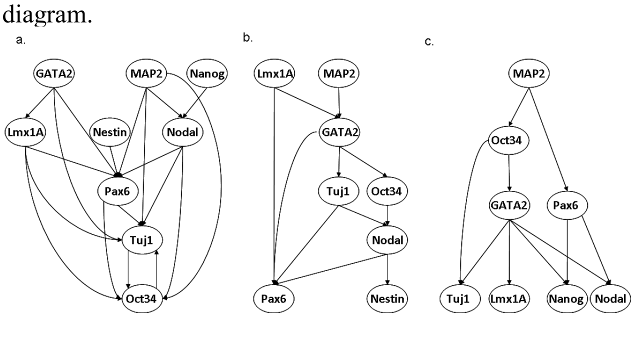


Figure 2. Initial network models.

The initial models which include summarized time-series information and concentration information. (a) Initial model of Acrylamide. (b) Initial model of Diethylnitrosamine. (c) Initial model of Thalidomide.

C. *Inferred Network by SEM*

The final inferred networks for each chemical and the estimated regression weights of the edges are depicted in Figure 3. The inferred networks of chemicals revealed distinct structures. In the inferred network of Acrylamide, many genes were arranged as exogenous objects, and only one gene was arranged as the final result of all regulation in the network. On the other hand, two serial regulations interacted with each other in the Diethylnitrosamine network model. One serial regulation was from Lmx1A to Pax6, and the other was from Tuj1 to Nestin. The signal input genes in the Diethylnitrosamine network were also different from those in the Acrylamide network. Even though Tuj1 was arranged as an output object in the Acrylamide network, Tuj1 was arranged as input in the Diethylnitrosamine network. The inferred network of Thalidomide was also different from both the Acrylamide and Diethylnitrosamine networks. In the Thalidomide network, only two genes were arranged as input objects, but four genes were arranged as output objects. This means that only a few genes will be directly affected by Thalidomide, but finally many genes were affected throughout the gene regulatory network.

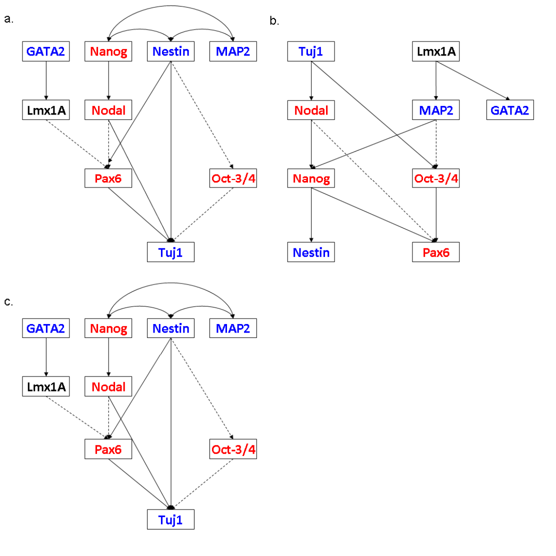
According to our inferred network, the differences between the gene regulation by chemicals were clarified, and the network shapes reflected the features of chemical toxicities. In the inferred network, the effects of Acrylamide toxicity finally aggregated to Tuj1, which is known to contribute to microtubule stability in neuronal cells [22]. Acrylamide is neurotoxic, and thus it is reasonable that the effect of Acrylamide finally aggregated to a neuronal cell-related gene.

As compared with the Acrylamide network, the cell differentiation genes were arranged at downstream steps in the Diethylnitrosamine network. From the carcinogenic features of Diethylnitrosamine [23][24][25], normal cell differentiation in the embryonic stem cell may be disturbed.

The most complicated structure was the Thalidomide network. In the Thalidomide network, several type of genes are finally affected by its chemical toxicity. Particularly, two cell differentiation-related genes, Nodal and Nanog, are important for normal early embryonic development. Nodal is related to the development of the left-right axial structure [26][27], and its signaling pathway is known to be important very early in development for cell fate determination and many other developmental processes [27]. Nanog is known as a key factor for maintaining pluripotency in embryonic stem cells [28][29]. Thus, the unusual expressions of these genes, which occurred due to Thalidomide toxicity, may have caused its harmful side effects.

IV. CONCLUSION

We applied an improved SEM approach to reconstruct a gene regulatory model from gene expression data in human embryonic stem cells, and we have shown that SEM is a powerful approach to estimate the gene regulation caused by chemical toxicity. The inferred networks clarified the differences between the gene regulation by chemicals, and the features of chemical toxicities were well reflected in the network structures. Thus, the network construction by SEM is one of the useful approaches for inferring the regulatory relationships among genes. Furthermore, the inferred



d.

Acrylamide			Diethylnitrosamine			Thalidomide		
parent	child	regression weight	parent	child	regression weight	parent	child	regression weight
GATA2	Lmx1A	0.919	Tuj1	Nodal	0.702	MAP2	Oct-34	-0.448
Nanog	Nodal	0.515	Lmx1A	MAP2	0.537	MAP2	Pax6	0.43
Nestin	Oct-34	-0.442	Tuj1	Oct-34	0.623	Oct-34	Pax6	0.951
Lmx1A	Pax6	-0.129	MAP2	Oct-34	-0.492	Nestin	Nodal	1.026
Nestin	Pax6	0.606	MAP2	Nanog	0.9	Nestin	GATA2	0.664
Nodal	Pax6	-0.844	Nodal	Nanog	0.284	Oct-34	Nodal	0.25
Oct-34	Pax6	0.643	Lmx1A	GATA2	0.636	Oct-34	Tuj1	-0.477
Pax6	Tuj1	1.145	Nodal	Pax6	-0.209	GATA2	Tuj1	0.183
Oct-34	Tuj1	-0.77	Nodal	Nestin	0.269	MAP2	Nanog	0.948
Nodal	Tuj1	0.933	Nanog	Nestin	0.843	Nestin	Lmx1A	0.831
MAP2	Nanog	0.968	Oct-34	Pax6	1.121	Pax6	Tuj1	1.002
MAP2	Nestin	0.944	Nanog	Pax6	0.428	Nodal	Tuj1	0.308
Nanog	Nestin	0.966				Nestin	MAP2	0.922

Figure 3. Inferred network by SEM.

The optimal model for each chemical, obtained by the developed SEM iteration procedure. A positive relationship between genes is displayed with a solid arrow. A negative relationship between genes is displayed with a dashed arrow. Gene names with blue characters indicate "neurodevelopment related genes", genes with red characters indicate "cell differentiation-related genes" and genes with black characters indicate "related to transcription of insulin". (a) Acrylamide model, (b) Diethylnitrosamine model and (c) Thalidomide model. (d) The estimated regression weights of all edges in the optimal models.

network among genes can be utilized for the estimation of a chemical's effect, from experimentally obtained expression profiles. The ability to identify expression profiles and the corresponding biological functions is expected to provide further possibilities for SEM in the inference of regulatory mechanisms by chemical toxicity.

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Mobile Data Modeling in Human Body “Network”

Bell’s Palsy Case Study

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***Abstract* —The mysterious Path physiology of Bell's palsy sometimes prevents doctors to understand this disease. A fine diagnostic and an enhanced recovery surveillance are crucial for physicians to deeply be aware of the disease mechanisms. Moreover, the analyses of the patients' states may lead to the proposition of new strategies to cure the illness. This paper attempts to supervise the patients’ state evolution through the modeling of the facial nerve stream as a moving object circulating into the facial nerve “network”. Its progression through this latter, gives indication about patients’ recovery advancement and the disease behavior. We also propose, in this work, an algorithm based on graph matching concepts and a visualization algorithm able to show the recovery process in time. As a result, we obtain a graph, tracking the facial nerve stream. Then, physicians can observe the recovery progress. Hence, identifing the occurrence of conduction problem preventing it.**

Keywords-Bell’s palsy recovery; Matching Algorithm; Moving Object; Visualization

I. Introduction

The body's networks allow sub-systems (i.e., digestive, brain, pulmonary) to run independently passing key information when needed. Once this information is blocked somewhere, it implies a dysfunction of the sub systems, which is diseases’ reason. In addition to that, the human body is a complex system succeptible to rapidly change; such instability may also give rise to severe disease.

Among these sub-systems, the facial nerve the failure of which causes facial paralysis that, despite the techniques that are used to accelerate recovery, effective treatment is not yet well defined. The treatment of Bell's palsy is variable [8] ranging from observation to surgical decompression. Among these treatments we opts for electromyography (EMG). The advantages of EMG [9] include that it is relatively inexpensive and is performed by a machine. It yields a lot of data that is continuous and scalar, increasing its apparent credibility. It can detect more subtle muscular activity than visual measurement, and is the only useful approach when movement is not visible. At each patient’s visit, doctors apply EMG until patients’ are completely recovering. This code is comprehensible by specialists and physicians but most of times patient doesn’t understand specialized language concerned with medicines which is characterized by pretentious syntax, vocabulary, meaning or graphics. We aim in this research to simplify the codification of the facial nerve and ensure its comprehension by patients.

To make our solution evolutionary, the Bell’s palsy patient recovery surveillance, we want to help physicians and care givers to ameliorate their treatment methodology; we adopted from a first an algorithm that produces a modeling for the facial nerve: a colored tree indicating segments in which the stream nerve is operational. In a second, for Bell’s palsy recovery process, we adjust the matching theory to graphs generated by facial nerve modeling to detect graphs commonalities and differences: this is ensured thanks to a matching algorithm.

The remainder of this paper is organized as follows: In Section 2, we present a literature review organized in two parts: on the first side, we present facial nerve modeling and on the one second side we discuss some matching algorithms and make a comparison between them. In Section 3, once facial nerve anatomy is well understood, we propose a Facial Nerve Modelisation in the aim to adjust graph matching to these graphs. Then, in Section 4, based on this model, a visualization algorithm was proposed. And finally, in Section 5, we summarize the work and propose new perspectives to be done in the future.

II. Related Work

A. *Bell’s Palsy Modeling*

Understanding the facial nerve anatomy was essential to reach our objective. Akaichi et al. [1] aim at supervising the states evolution of patients affected by facial paralysis leading to recovery. Modeling facial nerve stream trajectory data seems to be an essential step leading to perform our purpose. Moreover, visualizing the facial stream nerve trajectories may help physicians to understand deeply the disease through comparisons performed on patient state in

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time, or between different patient states. Among facial nerve components, they treated the bronchial motors (the muscles). First, a modeling of muscles using UML [1] class diagram gives rise to a graphic modeling of muscles. This muscles model will serve later to follow the evolution of the bell's palsy patient's state. This is the result of the Facial Nerve (FAN) algorithm [1], which takes as input the graph G representing the facial nerve graph and the muscles responses recoded in a table, and produces a colored graph ColoredG indicating the trajectories of the facial nerve stream. A trajectory in the Bell's palsy case is starting from the End_node linked to the considered muscle until the graph starting node I0. Green trajectories demonstrating that the facial nerve stream crosses this trajectory and a normal function of the muscle. Unlike to a red trajectory indicating a dysfunction of the muscle, hence the cut of the stream somewhere. This algorithm has a spatial and temporal exponential complexity. This is due to the storage of graphs at each medical examination and the pass through the graph when coloring trajectories. In this paper, we adopt the muscles modeling and extent it to add the visceral motor components (Glands) modeling and in a second we minimize the FAN algorithm complexity to a linear one. This will be discussed in details in Section 4.

B. *Matching Algorithm*

Homomorphism [10] is proven helpful in many areas; to apply it between graphs several algorithms have been proposed. Before proposing the algorithm appropriate to the Bell's palsy case, we present in the following some algorithm proposed in the literature. Among the basic algorithms, we quote the Hopcroft-Karp Algorithm originally was invented by John Hopcroft and Richard Karp in 1973 and has ever since been vital for computer science. The Hopcroft–Karp algorithm [2] is an algorithm that takes as input a bipartite graph and produces as output a maximum cardinality matching.

It runs in O ($\sqrt{|V|}*|E|$) time in the worst case with E is the number of edges in the graph, and V is the number of vertices of the graph. Hopcroft-Karp is one of the fastest algorithms that find the maximum cardinality matching on a bipartite graph. The algorithm uses the augmenting path technique as well. However, in order to speed up the working time instead of searching for paths one by one it looks for many paths in the same time. The way the algorithm works is that it continually increases the size of a partial matching by discovering and utilizing augment paths. The main idea is to guarantee that the length of the path grows in each step.

Afterwards, Haloui and Wang [3] propose a new graph matching algorithm for computing the similarity between graphs which proposes a novel approach to the search for the best matching between two graphs. The search process is decomposed into K phases. The promising mappings in each phase are extracted and their matching errors are computed. Given two graphs, the goal is to find the best matching between their nodes that leads to the smallest matching error. This matching error is computed by the dissimilarity between each pair of matching nodes added to the dissimilarity between corresponding edges. An E*V matrix (P) is introduced such E is number of edges and V is the number of vertex. A Pij element in P denotes the dissimilarity between i and j in two graphs.

Recall that graph matching can be applied to several fields. Later on, Remco et al. [4] focus on the application of graph matching algorithms to this similarity search problem. Answering a similarity search query involves determining the degree of similarity between the search model and each model in the repository. Similarity in this case can be defined from several perspectives, including the following:

- Text similarity: based on a comparison of the labels that appear in the process models (task labels, event labels, etc.), using either syntactic or semantic similarity metrics, or a combination of both.
- Structural similarity: based on the topology of the process models seen as graphs, possibly taking into account text similarity as well.
- Behavioral similarity: based on the execution semantics of process models.

The graph matching algorithms studied in this paper attempt to establish 1-to-1 correspondences between nodes in the compared process models.

The problem of measuring object similarity can turns into a problem of measuring object similarity turns into the problem of computing the similarity of graphs, which is also known as graph matching. In this paper, application of graph matching will be demonstrated giving examples from the fields of pattern recognition and computer vision.

The run time of this algorithm is O (βV^{2V+1}), where V is the number of vertexes in the input graph and β is a threshold that defines the maximum number of admissible edit operations. Therefore, this approach is limited to (very) small graphs. The graph matching algorithms reviewed in this paper are very general. In fact, there are no problem dependent assumptions included. The nodes and edges of a graph may represent anything, and there are no restrictions on the node and edge labels.

The graph matching is also applied to the field of image comparison and recognitions. Vertices in graphs represent regions of images, and the division in regions is the result of a segmentation procedure. Hence, automatic segmentation and graph construction techniques are applied to create the graphs that are to be matched. In order to consider a homomorphism as valid, all the vertices in the model graph will have at least a vertex in the data graph that has been matched to it. The complexity of the algorithm depends on the number of phases K. For a given K, to find the best matching we need O (V^2K^V) steps, where V is the number of nodes in the smaller graph.

A comparative study between four algorithm presented above is detailed in Table 1:

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TABLE 1. COMPARATIVE STUDY BETWEEN GRAPH MATCHING ALGORITHMS

Algorithm	Input	output	Complexity	Techniques used
Hopcroft–Karp	a bipartite graph	a maximum cardinality matching	O(√nm)	The augmenting path
Hlaoui and Wang	A(E*V) matrix	Similarity between graphs	$O(V^2K^V)$	Similarity matrix
Remco and al.	two business process graphs	Map set between the graphs		Greedy algorithm and pruning
Horst Bunke	A graph and a thresholdβ		$O(\beta V^{2V+1})$	

III. FACIAL NERVE MODELING

A. *Fcial Nerve Components Modeling*

Understanding the facial nerve anatomy [1] is essential to reach the main objective of our work. Indeed, facial nerve can be subdivided into two main components: motor components and sensory components. Essential motor components are the bronchial motor that efferent supplies the muscles of facial expression [6], and visceral motor that vehicles the parasympathetic innervations to all glands of head.

In this paper, we adopt the visceral motor. We subdivide the facial glands into two classes: the superior half glands and the lower half glands. The superior half glands are the eye glands which is the Lachrymal Gland (LG).

The lower half glands are ear glands, nose glands and the salivary glands. The ear glands are called ceremonious gland (CG). Nose glands are Nasal Glands (NG) and salivary glands which are composed by cheek glands and mouth glands. Cheek glands are the Parotid Glands (PG) and mouth glands subdivided into Sub maxillary Glands (SmG) and Sublingual Glands (SlG). Figure 1 describes visceral motor components details using UML modeling.

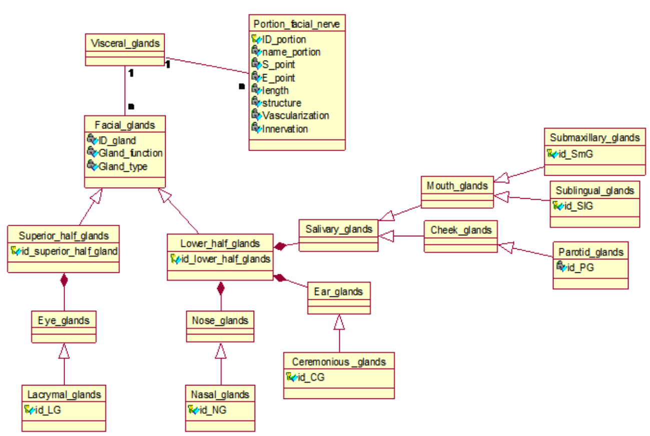

Figure 1. Visceral Motor Component Class Diagram

Understanding facial nerve anatomy permits us to better understand the Bell's palsy disease. Once facial nerve structure is established and facial nerve structure is analyzed. We note that to better understand this disease a graphical modeling of the structure can be the efficient way. A useful way of representing the knowledge is by using graphs. They have been proved as an effective way of representing objects [7]. For the visceral motor components, nodes represent intersection glands and arcs represent the connections between them.

The start node of the graph describes the beginning of the facial nerve of one side (the left side or the right side) of the face, the end-nodes represent facial glands, and arcs describe connections between nodes (Fig. 2).

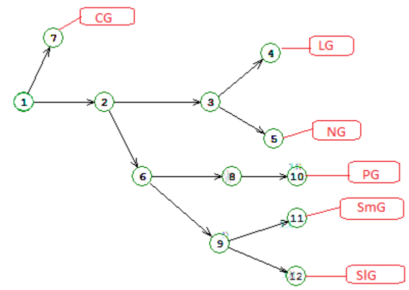

Figure 2. Facial Nerve Glands Graph

To better understand this graph, a mathematical formulation will be more suitable:

A graph G can be defined by a couple G (V, E) in which:

- V(G) is a set of nodes or vertexes:
  - Vertex (the root): the facial nerve beginning with a degree superior to 1 which the degree of a vertex is the number of edges that connect to it.
  - Internal nodes: facial nerve bifurcation with a degree superior to 1.
  - External nodes (or leaf): facial muscles or facial glands with a degree equal to 1 except the WM muscle.
- E(G) is a set of edges such that each edge eij=vi.vj connects nodes vi and vj where is a set of element pairs V. The edges here represent facial nerve portions which is the connection between nodes in wherein facial nerve stream circulates. The facial nerve stream circulates in one direction (a directed graph), this why we have an ordered pair.

The graph G can also be characterized by:

- A path: a unique sequence of nodes and is an alternating sequence of vertices and edges, beginning and ending with a vertex which in our case represent the trajectory of facial nerve stream from the facial nerve beginning until reaching a muscle or a gland.

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- The distance (D) of a path from vi to vn is measured by the length of the unique set of edges implicitly defined by the path. The length of a path here is the number of facial nerve portions composing the trajectory. D = V–1, where V is the number of vertexes visited (a vertex is counted each time it is visited). In our case is the number of facial nerve bifurcation.

B. MFGS Algorithm For Bell's Palsy State Evolution

Recall that the objective of this modeling is to supervise the patients' state evolution and see the recovery at each medical examination. The recovery is determined after a comparison between muscles and glands intensities computed using EMG and ENoG respectively of both sides: paralyzed and healthy. For two consecutive medical examinations, the evaluation of the disease is due to the comparison process between paralyzed graph obtained at the last medical examination and the current one of the paralyzed side.

Hence, the problem of supervising the patient's evolution turns into the problem of computing the similarity of graphs between the healthy side and paralyzed side, which is also known as graph matching.

Analogously to Bell's palsy, physicians need to match the muscle of the paralyzed side to those in healthy side to assess patients' disease recovery. This matching is based on the field intensity of each node more especially each leaf.

Given two node-labeled graphs G1 = (V1, E1) and G2 = (V2, E2), the problem of graph homomorphism is to find a mapping from V1 to V2 such that each node in V1 is mapped to a node in V2 with the same label, and each edge in E1 is mapped to an edge in E2 from a model graph to a data graph. The sense of matching depends on the healthy side and paralyzed side.

If there is a homomorphism from a graph G1 to a graph G2 we say that G1 maps to G2 and we write simply Φ: G1 → G2 which maps vertices to vertices and edges to edges.

In Bell's palsy application, matching a vertex to other one means automatically matching the whole trajectory or path from the leaf until the vertex. The matching is determined after a comparison of intensities. If we map a vertex in the model graph to other one on the data graph, this means that the muscle or gland has a normal function and the facial nerve stream crosses the entire path. Hence, all the edges belonging to the muscle path are matched automatically.

To connect two nodes, the following condition must be satisfied: the intensity of the leaf which refers in this case to a facial muscle or gland on the paralyzed side must be greater than or equal to that on the healthy side with an error margin.

The graph homomorphism is used to detect some metrics. Among them, we cite the measure graph similarity.

By analogy to Bell's palsy, graph homomorphism can be used to detect the disease progression. At each visit, EMG is applied to facial muscle for both sides. Thanks to a comparison of intensity for the same muscle at each side, we conclude the recovery or not for the muscle. Mixing EMG and homomorphism, physicians can detect the Bell's palsy recovery:

- The total recovery implies a complete matching from the healthy side's graph to the paralyzed side's graph
- The partial recovery implies a partial matching of two sides.

The number of nodes matched measure the graphs similarity. This metrics is based on the maximum of nodes matched; a completely matching or a homomorphism implies all the nodes in the paralyzed graph (data graph) are matched to nodes on the healthy graph (model graph) and finally as a conclusion we have a total recovery.

For finding matching with the maximum cardinality or the maximum graph similarity, we propose this algorithm:

MFGS Algorithm
Input: Two labeled graphs for healthy (Gh) and paralyzed (Gp) side
Output: Matching between nodes in Gh and Gp from the data graph to the model graph For each leaf in the paralyzed graph

1. **Begin**
2. HealthyLeaf=BFS(Paralyzed_graph.Leaf, Healthy_graph)
3. If (Compare (Paralyzed_graph.Leaf. Intensity, Healthy_graph.Leaf.Intensity))// a valid mapping
   Match (ParalyzedLeaf, HealthyLeaf)
   Match(ParalyzedLeaf.trajectory, HealthyLeaf.trajectory)
   Increment C
4. If (Total matching)
   Total recovery
5. Else
   Display Sub Graph matched
   Partial recovery
6. Return C
7. **End**

The BFS function (Breadth First Search) is a strategy for searching in a graph when search is limited to essentially two operations: (a) visit and inspect a node of a graph; (b) gain

access to visit the nodes that neighbor the currently visited node [5].
The BFS algorithm is as follows:

BFS Algorithm
1. Enqueue the root node
2. Dequeue a node and examine it
   - If the element sought is found in this node, quit the search and return a result.
   - Otherwise enqueue any successors (the direct child nodes) that have not yet been discovered.
3. If the queue is empty, every node on the graph has been examined – quit the search and return "not found".
4. If the queue is not empty, repeat from Step 2.

Matching algorithms are used to determine commonalities and differences between two structures. Differences can be due to the inequality of intensity of muscle for both sides.

Hence, the evaluation of commonalities gives raise of the structural similarity and the Bell’s palsy’s recovery. The oriented graph or the tree can be presented as an XML document. Hence, patient’s arborescence is saved in the form of a XML document. The above figure represents a part of an XML document for a patient at a visit:

```
<?xml version="1.0" encoding="UTF-8"?>
<Patient>
 <Name>Jabali Mariem</Name>
 <BirthDate>09-09-2005</BirthDate>
 <Gender>Female</Gender>
 <MaritalStatus>Single</MaritalStatus>
 <Location>Borj cedria</Location>
 <ParalyzedSide>Right</ParalyzedSide>
 <ParalyzesCause> dropped from a height of 3 m
</ParalyzesCause>
 <MedicalHistory>allergic to nothing</MedicalHistory>
 <Muscle classe="P2">
  <name>HED</name>
  <Side>Right</Side>
  <type>frontal muscle</type>
  <intensity>45</intensity>
 </Muscle>
</Patient>
```

The matching algorithm is exploited for the detection of the similarity of XML document. Evaluating these similarities is relevant for detecting the patient evolution and the degree of reaching of disease. Then, the similarities measured can be exploited for grouping together patient having the same characteristic. In order to obtain the best match between the two structures, common data contents must be maximal. Whereas, common data contents refer to same intensity if same muscle or glands for both sides: healthy or paralyzed. Then, we want to obtain a numeric value that quantifies the similarity between both sides. The evaluation similarity function is R. This function computes the ratio between the evaluations of common data contents C between the two structures (number of element having same intensity considering the error margin) and the evaluation of all elements A in the two structures (total number of muscles or glands). The obtained similarity value is a real number in the range [0, 1].

$$R=\frac{C}{A}$$

R=0 if there’s no similarity between two structures then minimal matching then totally paralyzed.
R=1 if there’s a perfect similarity between two structures then maximal matching then totally recovered.

A set of node pairs (x, y), M is called a matching from Gp to Gh iff:

- (x, y) ϵ M, x ϵ Gp, y ϵ Gh, signature (x)= signature (y)
- Qqs (x1, y1) ϵ M and (x2, y2) ϵ M; x1=x2 iff y1=y2 then one to one matching
- Qqs (x, y) ϵ M suppose x1 is the parent of x
  Y1 is the parent of y

Then x1, y1) ϵ M → M preserves ancestor relationships

- Suppose (x1, y1) ϵ M, (x2, y2) ϵ M } x1 is an ancestor of x2 iff y1 is an ancestor of y2

There are several steps in the algorithm:

1. Determining the signature of each nodes for both XML structures
2. Determining the matching set M
3. Generating the evaluation similarity function

Let us present the three phases in details.
Determining the signature of each node consists on browsing the XML document and for each element (muscle or gland) extracts the value of the attribute name and the value of the intensity, then concatenates them. This function returns a set of signature (string).

Extraction Algorithm
Input: an XML document
Output: a set of signature
1. Begin
2. For each line in the XML document
3. Extract element labels: name and value

4. Concat two lables
5. Save the signature// save the signature in S
6. Return S
7. End

Once all signatures are obtained, the matching function is applied.

MFGSI Algorithm
Input: two labeled graph and two sets of signature S
Output: a set of matching M
1. Begin
   2. M1= {all leaf nodes in Gh}
   3. M2= {all leaf nodes in Gp}
   4. Do {
   5. For every node x in M1
   6. For every node y in M2
      - If (signature (x)= signature (y))
      - Save matching (x,y) // save the matching in M
   7. Set M1=(parents node for previous nodes in M1}
   8. Set M2=(parents node for previous nodes in M2}
   9. }while both MA and M2 are not empty
   10. Return M
11. End.

In the case of partial matching, which refers to partial recovery, the algorithm may return the homomorphism sub graphs. By definition, given two graphs G and H as input, the sub graph homomorphism which are structurally and text similar. Analogously to Bell's palsy, the sub graphs homomorphism refers to facial part which is not affected by the disease. Later on, these sub graphs can be used for patient classifications.

C. *Example*

In the following, we present an execution example for a patient at each medical examination. So we can see the patient's state evolution through the graphs matching:
At the first visit, doctors detect a Bell's palsy in the left side. Hence, EMG is applied to both sides. As the left is affected, physicians use intensity computed in the right side as a threshold.

Applying the algorithm we obtain this matching, matched nodes implies the matching of the whole trajectory from the root until the leaf (Muscle or glands). In this example we focus on the muscles.

During the first examination, physicians detect with some exercises the incapability of smiling and an asymmetrical smile, light sensitivity, the difficulty of blinking, and difficulties when speaking. These muscles weakness are proved later using EMG. Once EMG is applied, two labeled graphs are created, one for each side containing muscles characteristics which are: name and intensity. The goal is to find the matching set M and evaluating similarity.
The first step is to store the muscle intensities in an XML file:

```
<?xml version="1.0" encoding="UTF-8"?>
<Patient>
<Name>Jabali Mariem</Name>
<BirthDate>09-09-2005</BirthDate>
<Gender>Female</Gender>
<MaritalStatus>Single</MaritalStatus>
<Location>Borj cedria</Location>
<ParalyzedSide>Right</ParalyzedSide>
<ParalyzesCause> dropped from a height of 3 m
</ParalyzesCause>
<MedicalHistory>allergic to nothing</MedicalHistory>
<Muscle Date="January 25, 2007">
<name>HED</name>
<Side>Right</Side>
<type>ChM</type>
<intensity>75</intensity>
<type>EM</type>
<intensity>50</intensity>
<type>EyM</type>
<intensity>35</intensity>
<type>FM</type>
<intensity>30</intensity>
</Muscle>
</Patient>
```

Then, we compare the muscles intensities. To do this, signature of each muscle has to be created on which then the comparison is based.
The sets of signature:
S1={ChM75, EM50, EyM35, FM30, HAM76, LLD98, LLM81, MAD87, MZM95, NeM54, NoM90, NsM91, PoAM110, PrAM135, RM78, TM70, ULM53, SZM76, WM100}
S2={ChM88, EM101, EyM90, FM94, HAM76, LLD120, LLM121, MAD86, MZM93, NeM92, NoM87, NsM88, PoAM105, PrAM132, RM76, TM78, ULM88, SZM101, WM96}

These two sets M1 and M2 are the input of the matching algorithm added to the two labeled graphs. When the algorithm is over, we obtain as output a set of matching:
M={{ChM75,ChM88};{HAM76,HAM76};
{MAD87,MAD86};{MzM95,MzM93};{NoM90,NoM87};

{NsM91,NsM88};{PoAM110,PoAM};
{PrAM135,PrAM132};{RM78,RM78};{WM100, WM96}}
Then the ratio of similarity is computed:
$R = \frac{\text{number of couples nodes matched}}{\text{number of couples nodes}} = \frac{10}{19} = 0.52$
This ratio determine the gravity of Bell's palsy, in this case the patient have a paralysis with 0.52 gravity.
In addition to the sets of matching, we can display the matching using graphs as shown in Figure 3:

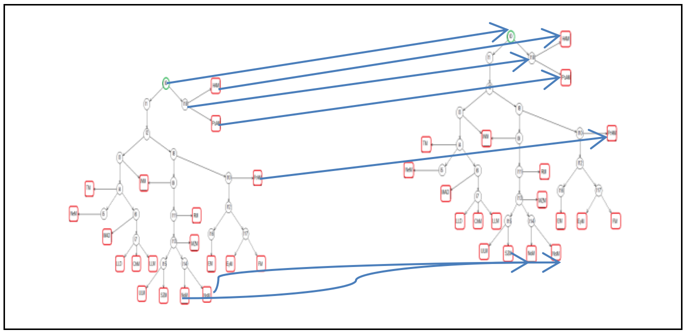


Figure 3. Matching between healthy and paralyzed side

This algorithm is applied at every medical examination. At the second one, we keep the same sets of matching by adding some couples recovered after treatments.
M= M U {{FM94, FM94}; {EyM90, EyM90}; {EM50, EM50}; {ULM89, ULM88}; {SzM101, SzM101}}
$R = \frac{15}{19} = 0.78$

Finally, at final medical examination, which corresponds to a totally recovered patients we have all nodes matched and a ratio equal to 1.

Collecting ratios computed at each medical examination, it can show the disease gravity evolution through the time. This is explained by a designed using Matlab in Figure 4:

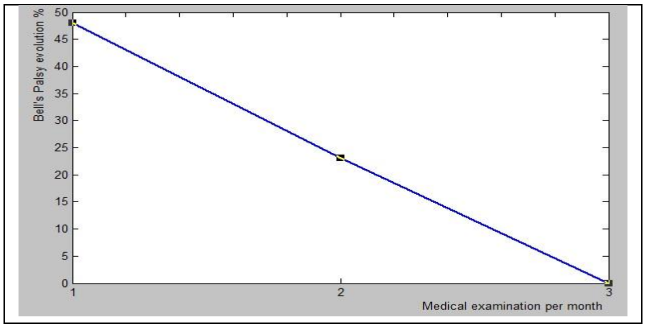


Figure 4. Disease Gravity Evolution

IV. FANI ALGORITHM VS. FAN ALGORITHM

For FAN Algorithm [1], for each execution, it has as input a graph G refers to the facial nerve structure and a table containing muscles or glands intensities and their thresholds. As output we display and store a colored graph indicating the recovery process. In terms of spatial and temporal complexity this can costs a lot. The temporal and spatial complexity when dealing with trees depends on the number of nodes. Suppose V nodes' number; the complexity is 2^V, hence this complexity is exponential. We aim in this part to optimize the complexity of the previously proposed algorithm.

The storage of patients' trees is expensive in terms of spatial complexity due to the data structure used and a high time complexity when following the entire route of the trees at each medical examination. Knowing that all patients have the same facial nerve structure so same tree structure, the differences on the trees are localized at the last layer. This layer consists of trees' leaves: muscle or glands and their characteristics. Among the characteristics, the most important one are muscles or glands name and intensities. For coping to the complexity issue and based on structure commonalities and differences, the solution is to store one and only one generic tree without her last layer, which means without leaves which refers to muscles or glands. For muscles or glands, storage is done in forms of table containing muscle name and intensities.

For each patient and at each medical examination, an intensities table is stored containing muscle or glands intensity and the examination date, and then comparison is between two tables of two different consecutive medical examinations. Hence, once the visualization process is triggered, the tree is created by combining two parts: the common part that is saved to the generic structure and the table containing the intensities representing the leaves of this tree. Thanks to this storage, the complexity of intensities complexity has decreased from an exponential to a linear complexity: from O (2^V) to O (V) with v is nodes' number.

Following these changes, the FAN algorithm has evolved. It takes as input two intensities table: T1 and T2; T1 contains the intensities of the paralyzed side and T2 contains the intensities of the healthy side called the threshold. Than the comparison is based on those two tables. Once, the user wants to see the patient's state, the generic graph is concatenated with muscles stored in table 1 and based on the comparison the colored graph is displayed; so the backup is only for tables containing intensities and threshold.
The algorithm is as follows:

Algorithm FANI
Input: Table1, Table2
Output: a colored graph
1. Begin
  2. Compare (Table1, Table2)
  3. Concat (GenericGraph, Table 1)

4. For each leaf in graph
5. Color_trajectory(leaf, root, red)
6. Color_trajectory(leaf, root, green)

7. End.

For each patient and for each medical examination an intensities table is stored:

Algorithm Storage

1. Begin

2. For each medical examination
3. Compute intensities
4. Save in Table1
5. Compute muscle threshold
6. Save in Table2
7. Return Table1, Table2

8. End.

EXAMPLE:

We took the same case presented above in the matching theory.

The intensities computed are stored under this format: the intensities are ordered in an alphabetical order of muscles:

ChM	EM	EyM	FM	HAM	LLD	LLM	MAD	MZM	NeM

NoM	NsM	PoAM	PrAM	RM	TM	ULM	SZM	WM

Once the EMG technique is applied to all facial muscles; we obtain these values stored in two different tables. Each one for a special sides: paralyzed that will serve for comparison and healthy which will serve as threshold.

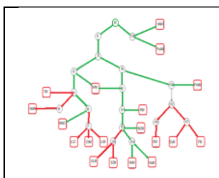
75	50	35	30	76	98	81	87	95	54

90	91	110	135	78	70	53	76	100

88	101	90	94	76	120	121	86	93	92

87	88	105	132	76	78	88	101	96

To supervise the patients' state, the colored graphs can be displayed in order of medical examinations.



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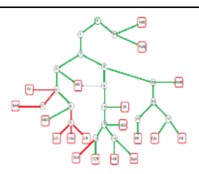

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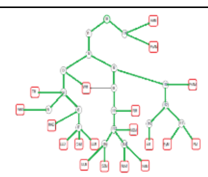

24 March 2007

V. CONCLUSION AND FUTURE WORK

Bell's palsy disease is the origin of a physical suffering, and has an emotional and psychological impact on patients. To contribute in the improvements of treatments and analysis automation, we proposed clear and concise modeling, we also represent it using a graph leading to track facial nerve dream and to determine by the way patients' recovery progress and eventual conduction problems to be solved thanks to observation. This is ensured thanks to an algorithm based on matching theory which produces as output similarities between graphs and the disease gravity.

Future work will focus on integrating manipulated data resulting from treatments performed on various patients by a range of physicians in a various health care institutions. This, obviously, will enhance analysis and large-scale exploitation of these data which is difficult and complex.

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Personal and Social Communication Services for Health and Lifestyle Monitoring

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Abstract—**The focus of the PAL project is to study how future requirements for healthcare services impact current and future communication infrastructures. Current assisted living scenarios work only in restricted environments and are unable to provide continuous user support. Systems in this space tend to be closed, providing only particular functionality and/or operating on specific infrastructure. Our aim is to deploy appropriate interface and interaction paradigms, regardless of the underlying networking and software technologies, to enable users to achieve self-monitoring and self-management of their lifestyle and health. We also consider the integration of social and professional support networks, while ensuring appropriate access controls. This paper details a layered architecture for supporting a diverse range of care services. We provide an integration framework to demonstrate the practicality of our approach, and present results highlighting design considerations for user-centric care systems.**

Keywords-self-monitoring; lifestyle; healthcare; privacy; security; communications; networks; middleware

I. INTRODUCTION

The number of people living with long-term health conditions is growing as people's lifespans increase, placing a heavy burden on healthcare systems and support networks. Data from the World Health Organization shows 75% of the total population with one chronic condition and 50% with two or more conditions [1]. The risk factors for chronic diseases are often related to lifestyle choices like smoking, alcohol intake, physical inactivity, or poor diet. Lifestyle choices have such an influence on health that prevention of disease through self-monitoring is becoming increasingly important.

Self-monitoring systems give people additional knowledge to understand the effect that their actions have on their well-being and support them in making better lifestyle choices. Prevention can make a real difference for the low risk category of patients, around 70-80% in the UK [1]; with suitable support and engagement they can learn how to manage their conditions and prevent further deterioration.

Monitoring and communications technology have developed to the extent that they are potentially exploitable in large-scale, widespread healthcare. At the same time, people are becoming increasingly familiar with and accepting of a wide range of technologies. The time is right to consider technology-assisted lifestyle monitoring to help in detecting and preventing chronic diseases.

Despite technological improvements, we are in danger of fragmentation in healthcare provisioning if the current approach of developing vertically separated applications continues. In other words, solutions tend to operate in "vertical silos". As a consequence, they are typically restricted to a single domain, for example, working on a single device or within a managed network. Instead, solutions are required that operate across domains, be they organisational, networking, or even device specific. Open systems solutions must adapt to a variety of applications and services, through communication and networking layers that operate across domains. Within our project, entitled *PAL (Personal Assisted Living)*, we envisage a multi-domain system comprising patients at home and outside, primary care practices, hospitals, and outsourced services (such as X-rays and emergency response teams), where components are used and reused to meet the functional requirements across the range of care-related applications and services.

To make such a vision manageable we have started from a number of use cases that highlight the requirements motivated by the above: (1) Prevention of disease onset or deterioration through lifestyle and health monitoring; (2) Integration of social and professional networks; (3) Mechanisms for information governance; (4) Dynamic coordination of system components to realise functional goals; (5) Operation across organisational and communication domains. Section II presents a lead scenario to exemplify these issues, outlining the main challenges for developing a holistic systems solution for healthcare provisioning.

We address these challenges through providing an integration framework, so that a range of applications can be deployed above a middleware layer under which a variety of communications technologies can operate, while supporting diverse device technologies. From the perspective of information management, our framework supports data recording, analysis, retention, usage and audit across the boundaries at the application, network and device level. From the (patient) users' perspective, their data is sensitive and private and we support the specification and enforcement of security policies. Moreover, we envisage the involvement of

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social and professional networks of carers, particularly as users become less able to cope alone. Controlling data access becomes more subtle as more users (roles) become involved.

All of these aspects are realised in the PAL architecture presented in Section IV. It is this architecture and the presentation of its on-going realisation that is the core contribution of this paper. We recognise that the envisioned system and its early prototyping in a lifestyle management setting is only a first step towards an integrating framework for the healthcare application industry. We believe, however, that our work can provide useful insights in the relevant areas of development. In addition to our integration approach, we also outline experiences with certain aspects of a working system that we built based on our approach. We outline important aspects regarding the system components that we implemented and present first results from user experiments.

We begin with a scenario to highlight the challenges in provisioning healthcare systems, and follow with related work. Section IV details our architecture, and in Section V we describe the realisation of our framework and present results illustrating design considerations for user-centric systems.

II. Lead Scenario and Challenges

Let us first present our lead scenario in the area of lifestyle management. We will use this scenario to highlight the various challenges that exist for realising a system-wide solution for healthcare provisioning.

A. *Lead scenario*

Oscar is a patient-user who has chronic heart disease and needs to pay attention to his wellbeing. His related blood pressure issues make him susceptible to fainting. Since he was diagnosed, Oscar started using the PAL system to collect information about his daily activities, and physiological data relevant to his condition. PAL provides Oscar with support within a *preventative* mode as well as a *reactive* mode. In the preventative mode, the system allows Oscar to track his wellbeing by interpreting and visualising collected data in personalised ways. It also allows Oscar to share certain information with his support network (e.g., family, friends or healthcare specialists). In the reactive mode, the system can provide emergency support, e.g., during an fainting episode.

B. *Main system challenges*

Self-monitoring is all about information pertaining to an individual. We therefore divide the system challenges into the dimensions of *gathering and providing* information throughout the system, *processing and using* the information, as well as *governing* the information according to defined policies.

When gathering and providing information throughout any self-monitoring system, it is important to recognise that assisted living data may be collected from a wide variety of sources. Multiple types of data may originate from various user devices, such as mobile phones, laptops, PCs, body sensors and environmental sensors. The information used may include location, movement, ECG, heart rate, environmental context (e.g., noise levels, temperature, weather, pollen levels, etc.), social context, messages, calendar events, and many more. In addition, available knowledgebase sources, such as NHS Direct [3], could be integrated into the processing step, i.e., gathered information is aggregated and interpreted through wider community knowledge. Each data source may play a role in meeting a number of functional goals, across a range of applications; for instance, an ECG sensor may provide information relevant to applications for a patient-user when exercising, their GP for analysis/diagnostic purposes, and for paramedics in dealing with an emergency. The relevance of information to applications will vary, depending on the circumstances. As described in our lead scenario, we consider two usage modes: *preventative* and *reactive*. Due to the different requirements, the preventative mode focuses more on storage, high-level processing, visualisation, and policies for sharing and remote access. Given the plethora of information being gathered in the preventative usage mode, understanding the information is particularly challenging for system users. Hence, any visualisation needs to go beyond traditional graph-based approaches to achieve the awareness that our users need.

The reactive mode is mainly concerned with reconfiguring data streams at runtime, respecting the various control policies as well as the heterogeneity of the underlying infrastructure. For the latter aspect, it is particularly important to avoid restricting any solution to single domains but rather to work over a variety of available communication technologies as they happen to be available. This requires that the supporting communication infrastructure facilitates information exchange between a wide range of data sources and sinks in a dynamic, context-aware, and multi-domain manner. For that, knowledge of network capabilities, such as availability, link failures, etc., is crucial. While this information is not used directly by end users, it is important for the provisioning of seamless services, for example when users move from indoors to outside or when patients move between areas with variable connectivity.

Clearly, heterogeneity places a heavy burden on any application that is directly exposed to these issues. Hence, abstracting the communication specifics through a common interface is important, aiding the re-use of functional components across use cases. The level of abstraction that a healthcare application shall be built upon is that of information flows that can be controlled in terms of gathering, processing and usage, all under a common policy framework that defines the security properties of the information flow. Such a policy governance framework is important, given the personal nature of the information considered in our scenarios. While encryption of information is important, governance extends to context-aware policies defining access to flows of information (even if encrypted), forming appropriate communication relations (e.g., between doctors and care personnel), and the ability to override standard policy (e.g., in cases of emergency).

We now present a brief overview of related work before outlining our architecture, focusing on information gathering, provisioning, processing, presentation and governance.

III. Related Work

Self-monitoring solutions of different kinds have been well studied in academia and corporate research during the past years, with areas such as health and telemetry [9][10] being well represented within the commercial space. Some examples are movement and fall detection systems, such as WristCare

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[11], SenseWear BMS [12], Philips LifeLine [13] and the Wellcore Emergency Response System [14], or heart monitoring solutions such as t+ blood pressure [15], HealthBuddy [16], and CardioNet [17]. For most of the existing solutions, data is stored on a remote/central server and analysed by professionals; in some cases patients might be able to add certain notes, symptoms, and so on, and receive feedback from medical staff. Mostly, the systems are integrated into a purpose-built device, while mobile phones are merely used as an interface device, to input data or to receive alerts.

With the availability of sensors such as the Alive Heart and Activity Monitor [18] that can be connected via Bluetooth to recording devices, such as mobiles or laptops, mobile devices can also be used for providing self-monitoring solutions. For example, MobiHealth provides a suite of physiological data recording through mobile phones [19], where various sensors can connect to the phone and use it to transmit data to a server. As smartphones become increasingly popular, and already include sensors such as GPS and accelerometer, fitness and assistance applications are appearing (e.g., iFall for Android [20], Sports Tracker for Symbian [21], or Endomondo [22]).

Common to all these related approaches is the purpose-built nature of their solutions. What is lacking is a system approach that addresses our identified challenges from Section II through a coherent and holistic design. The following Section IV outlines our contribution to providing such a system solution.

IV. PAL SYSTEM

A. System Architecture

The PAL core architecture follows a traditional layered structure where the middleware masks details of the underlying communications by presenting a communication interface to components that run above it. Although such a middleware can support applications directly, we have developed an additional lifestyle assistant layer capable of providing a higher-level interface to support users during self-monitoring in preventative mode. Other applications can coexist with the lifestyle manager by working directly above the middleware layer, so the infrastructure is generally suitable for supporting pervasive healthcare environments. For example, during reactive mode, external components are coordinated to respond to an emergency situation, as later described.

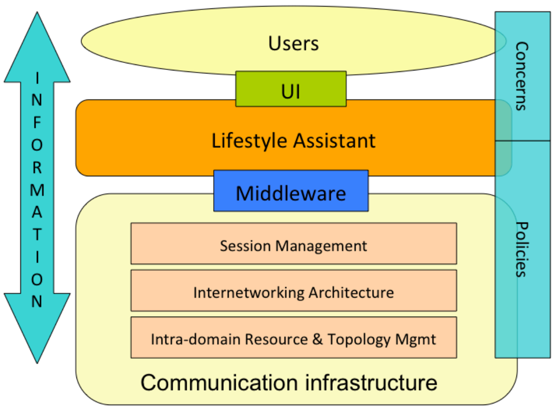

Figure 1. High-level component view of the system.

Figure 1 presents a high-level view of our system. In addition to the traditional layered components—the application (the lifestyle assistant), middleware and communication layers—we highlight the integration of information, its structures and its governing policies across all levels, from the user level right down to the communication and routing levels. Based on this integration framework, we provide in Section V an example of a working system that we realised alongside our lead scenario of lifestyle management. In addition to the realisation of our framework, we also outline first experiences that end users had with this system.

B. Information gathering and provisioning

In our system, much data is provided by sensors—physical (e.g., body or environmental sensors), or virtual (e.g., activity information derived from calendars, social interactions, application usage)—within a heterogeneous environment (see [2][7][7] for more information on gathering capabilities).

To assist in managing the diversity of sensor-produced data, PAL uses a gateway-based design, in which sensing gateways encapsulate the specifics of the particular data to be integrated, such as the implementation of a wireless sensing protocol, and/or access to a particular database or converting low-level sensor data into a format that can be understood by other components in the system. A gateway is therefore responsible for a first level of filtering and abstraction of information. In practice, the scope of each gateway will depend on the particular sensors involved: some gateways might operate to manage, aggregate and transmit the data of a number of different sensors and/or sensor networks, while others may be comparatively lightweight, e.g., tied to a particular sensor, such that it appears as though the sensor directly interacts with other components in the system. Once data has been gathered from various sources, information is provisioned for processing and presentation. Data must flow to a range of different applications and components in order to achieve particular functional goals. Since healthcare is a highly data-driven environment, we provision information as events that are relevant to other components. An event can encapsulate health-related information, including observations such as sensor readings, doctors' notes or a perceived emergency; as well as actions, such as the press of a panic button. Clearly, events will be relevant to a range of different applications/components, as appropriate to the particular circumstances.

Middleware provides a layer of indirection between applications/services and the underlying infrastructure. The role of the middleware is to facilitate interoperability, to provide a reliable mechanism for the exchange of information between system components and services. In PAL, we extend *StreamBUS* (*SBUS)* [4], which is a middleware for managing the exchange of messages (encapsulating events/data) between system components. SBUS was specifically designed for managing streams, enabling dynamic system reconfiguration (connections/disconnections and altering privileges), and providing content-based *publish/subscribe* semantics. However, it aims to be all-encompassing, by also supporting more traditional *client-server (RPC)*-based interaction paradigms (see Figure 2). This is important, as communications middleware supporting pervasive healthcare environments must provide for a number of interaction types, to enable a wide range of application-level functionality.

Each application/service in the system becomes an SBUS component, leaving the middleware to manage the communication concerns on its behalf. Data is encapsulated in typed messages (representing events), which are transmitted to other components in the system. The middleware ensures type-safe communication, and enables content-based filters to be imposed on communication channels. From an architectural perspective, much of the provisioning is implemented in the middleware using a *publish/subscribe* semantic, meaning that communication encapsulates the events themselves.

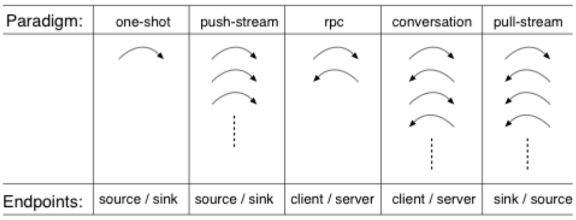

Figure 2. SBUS Interaction Paradigms.

Middleware is a natural point for policy management and enforcement, as it is independent of specific application and network concerns. From the middleware perspective, policy concerns dynamic reconfiguration in response to particular changes in circumstance: specifically, initiating/terminating data flows and/or changing privileges. In environments, such as assisted living, that consist of many data sources, forcing each application to initiate and manage its interactions quickly becomes infeasible (hence the application-specific silos of today). It follows that management increasingly concerns *coordination*: where particular circumstances (events) determine the interactions between applications. Policy operates to dictate how/when particular system components should (or should not) interact to meet the functional goals of a range of applications. In our infrastructure, we have developed a policy engine to manage these concerns. We implement a policy engine within database infrastructure (PostgreSQL), where policy is encapsulated in a set of rules (triggers). A rule is (automatically) executed on a particular change in context, which can operate to: a) raise an alert; b) effect a middleware reconfiguration (e.g. alter a privilege or connection); and/or c) change the active rule set (e.g. to enable a different set of governance policies to apply in an emergency situation).

As illustrated in Figure 1, immediately below the middleware layer is the PAL *communication infrastructure*. It is composed of two key functional sub-systems: session management and inter-networking. Session management ensures that an assisted living application session (e.g., an ECG stream) is kept running continuously when the application device switches from one wireless network to another (e.g., from an indoor WiFi to an outdoor 3G base station) due to user mobility and changes in network availability. The ultimate goal is to provide always-on connectivity to mobile clients, if/when required. For this, we consider an environment where different types of wireless networks co-exist. Typically, when the point of attachment changes, the device's address will also change, and as a result the application session is dropped. To solve this problem, a medium-independent gateway (MIG) has been designed to switch between different types of networks while ensuring session continuity. The essence of the MIG is a tunneling technology which hides any network interface (Layers 1, 2) and IP (Layer 3) changes from the upper layers, thus providing a virtual always-on available gateway. Such a tunnel enables the mobile device to physically join networks that belong to different administration domains without interrupting any on-going connections/flows. This method effectively simulates the behaviour of Mobile IP (MIP) [5] where a Home Agent (HA) is used instead of a tunnel end-point. An algorithm is implemented that carries out network selection based on an individual network's status such as signal strength, bandwidth, energy consumption, cost, etc.

While the MIG is more concerned about heterogeneous *wireless access* networks, the PAL communication infrastructure also addresses *wired core* networks. In particular, a clean-slate approach to internetworking called Information Centric Networking (ICN) [6] is adopted as an IP alternative. Its key task is to conduct route calculation and packet forwarding that directly operates on information items rather than endpoint addresses. The ICN software used is called Blackadder [23], which was developed in the context of the EU project PURSUIT [6]. Blackadder has been slightly tailored in terms of network interfaces and integration with the MIG to accommodate the PAL requirements. Specifically, we developed a link-aware *topology manager* (TM) that makes use of network link status information to assist *route calculation*. The calculated routing paths connect the sources of the information (publishers) with the destinations (subscribers) utilizing the underling publish-subscribe semantic of ICN. The key contribution here lies in enabling *differentiated dissemination* of information; a requirement that we see as important in future healthcare environments. For instance, in cases where certain information, such as heart rate, is deemed more critical than others, an information-centric approach to infrastructure allows for differentiating this specific information compared from other, less important, without resorting to cost-intensive solutions such as deep packet inspection (DPI). In addition, the focus on information dissemination in contrast to endpoint connectivity (as in the current IP-based Internet) allows for realising scenarios where applications are primarily concerned with receiving particular information rather than connecting to a *specific* source for this information. For instance, an application can simply request heart rate data rather than discovering the particular sources (and the specifics that are concerned with contacting these sources) that might potentially provide heart rate data. Hence, we believe that such an information-centric infrastructure approach greatly enhances the capabilities of application developers through providing an information-centric interface for information-rich use cases.

C. Information processing and presentation

In pervasive care environments, information will be relevant to a number of different applications and system components, that use data in a variety of ways, e.g. for processing, aggregation, storage, presentation, etc. Sometimes information can be provisioned in its original form (as produced by the information source), but often it requires further processing in order to fit its intended purpose.

In our preventative scenario, further processing of the information collected is vital so that Oscar can more easily understand what happens during each day based on data collected. A different kind of processing is required when certain information is shared with other parties within his support network. For the PAL lifestyle assistant application, we use context type-based information processing, which groups the various sensors into several main categories: *emotional*, *social*, *availability*, *mental* (*interest*), *activity*, *physical/spatial* and *temporal*. Within each context dimension, we use a rule-based system that can convert recorded data into high-level information based on various expert or individual experience-based knowledge bases. Additionally, the patient-users can provide their own interpretations either during the recording (i.e., through phone widgets) or later, at the time of visualisation.

Collected data forms the basis for various visualisations created to help users understand causal relations between their actions and their wellbeing. Such visualisations present information at various levels: detailed (e.g., timeline graphs), summarised (e.g., word clouds for text-based data), and correlated abstractions. The last type is a novel type of visualisation we have developed inspired by human storytelling [7]. For that, we process information along a story line by bringing all available (and processed) information together in order to create a summarised (and more engaging) view of the important events during a day. Figure 3 shows an example of an event within a daily story.

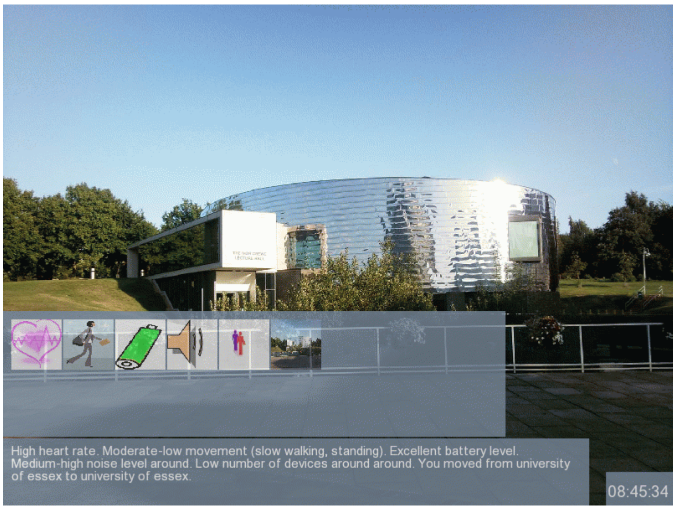

Figure 3. Example of an event within a story.

By providing multiple levels of detail within visualisations, we created a system that can support various types of user interactions and purposes. For example, while a story can show the main events during a day, the user (either as patient or healthcare specialist) can use detailed visualisations to focus on specific aspects, such as heart rate variations over time, social interactions over time and in certain locations, and so on.

Within the reactive scenarios, the coordination of applications and services underpins information processing and presentation. In PAL, we use the dynamic capabilities of SBUS to connect system components as appropriate to achieve particular functional goals. For instance, should a carer wish to visualise a patient's live heart rate data, their (presentation) application must be able to find and connect to the relevant ECG stream. Sensor streams might also need to be directed to an inference engine to detect a change in state and raise alerts; e.g. when Oscar has fainted and not moved. Some connections might be triggered by policy, e.g., automatically connecting an emergency service to a patient's data streams (e.g. location, vital-signs) in situations of a perceived emergency.

D. Information governance

Personal information is inherently sensitive. Therefore, we must protect data at all system levels. The patient must be able to describe the circumstances in which particular information is disclosed to particular parties. Such policy is context-sensitive, as restrictions will often vary according to circumstance.

For the scenarios of both modes to work, subsets of Oscar's records need to be available to a number of different groups. These may include families, friends and neighbours, local GP practices, hospitals, paramedics and ambulance crews. Members of each group should have access only to the appropriate parts of the records and only for the appropriate length of time. Health and welfare records may include many different items in many formats, e.g. emails, photos, sensor readings. To deal with this, PAL applies protection directly to the items of sensitive data. These protected items can then be safely stored and transported on any medium as the data remains safe wherever it is, such as on servers, wired or wireless connections or stored on a disk or USB devices. Access to the data is controlled according to policies defined by Oscar and enforced using policy based authorisation. This allows them to share his records while maintaining control over who can see them and under what circumstances.

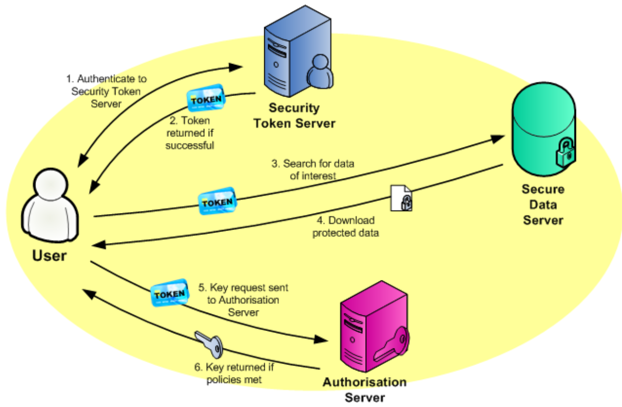

Figure 4. Token-based security mechanism

PAL users are identified within the system by using a token asserting the user's identity and attributes (e.g., a role). Tokens are issued by the Security Token Server (see Figure 4) once the user has been authenticated. When a user has a token they can obtain Oscar's data by connecting to a (live) data stream or by searching a Secure Data Server for archived data. The data is protected by encryption and the decryption key must be retrieved from the Authorisation Server. The Authorisation Server will check the credentials contained in the user's token and the information about the data object against the set of security policies. Access to the data will only be granted if the policy conditions are satisfied. A decryption key will then be returned to the user and they can decrypt the object and access the data. Since many parties are producing and consuming data within PAL, the system has been designed to operate within more than one administrative domain. Each domain can contain an instance of the components described above.

In addition to encryption, policy operates at runtime to govern information exchange. Each component maintains access control policy dictating the components with which it may interact. The SBUS middleware enables these privileges to be dynamically changed, which allows, for example, the relaxation restrictions in an emergency. Further, dynamically enforced policy enables granular, context-based control. For instance, policy might dictate that a homecare nurse is automatically disconnected from a patient's data streams when she physically leaves the patient's home. Both of these features are implemented by a dedicated, patient-centric policy engine that operates to trigger SBUS reconfigurations in response to changes in circumstance.

Patients undoubtedly have specific concerns, e.g., that their location should be hidden in normal circumstances, or that a GP cannot access their data unless explicitly authorised. However, it is unrealistic, if not dangerous, to expect a patient/user to define all situations in which disclosure is appropriate. This is because the typical patient will neither have the knowledge nor expertise to precisely determine the information relevant to each party. In practice, we expect that disclosure policy will be influenced by care providers, possibly through the use of policy templates that describe particular interactions. Any involved party is implicitly responsible for protecting health information, and thus must adhere to any specific patient preferences.

V. Bringing the Pieces Together

So far, within our project, we have focused on designing, developing and testing the main system components and functionality needed to realise the two main scenario modes (preventative and reactive) as well as the security and privacy framework described above. Our current work is to bring such pieces together within a combined prototype, following the integration framework. Here, we present details of our existing working system components and certain relevant results collected through our user-based experiments.

A. The Lifestyle Management System

Following the *preventative* part of our lead scenario, we developed a lifestyle management system that collects, processes and visualises various types of user information. For realising the system, we use various input sources for obtaining valuable information about a user's lifestyle. The recording scenarios had to reflect real lives as much as possible; therefore we considered a mixture of mobile and stationary sources, such as mobile phone, desktop, laptop, wearable physiological sensors and content servers. Through such sources, we are able to collect a large variety of information, as shown in Figure 5.

It is important to note that the types of information considered within a specific scenario highly depend on user preferences and constraints, the available sources within certain scenarios as well as on the relevance of information to such scenarios. A large amount of information is collected through the *AIRS (Android Remote Sensing)* platform [7], which benefited from our user-based experiments to extend towards incorporating more sensors as well as user-based annotations for mood and important events.

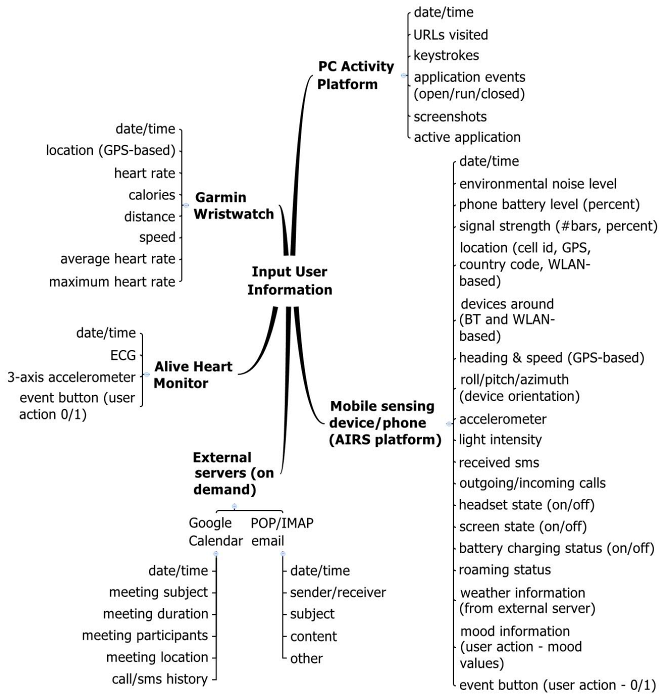

Figure 5. Information and sources.

The gathered data is secured and stored in a user-controlled database. Given that our solution is currently not embedded into a particular healthcare environment, the security token framework described in Section IV.D was not integrated.

Our system processes the gathered information along the context dimensions mentioned in Section IV.C for determining, for instance, activity, location, or environment information. This processing directly supports the visualisations towards the end user, both at detailed and abstract level. For this, the story-based approach presented in Section IV.C is realised (with Figure 3 showing an example story fragment). In addition, we allow end users to view detailed information at various levels, such as ambient noise level over time, crowdedness as determined by Bluetooth-enabled devices around and so on. The end users can have access to their data (either recorded or obtained on-demand) through a blog-based interface. This 'diary' style of visualisation lends itself to a natural form of end user interaction, allowing for the selection of particular days, archiving by month or amending gathered information with personal entries.

In addition to the preventative part of our lead use case, we also realised certain aspects of the *reactive* side, such as the

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information routing at middleware and infrastructure level (see Section IV.B). Hence, we utilise the information routing approaches, either through the SBUS middleware over an IP infrastructure or through directly routing on information within an information-centric networking test bed. We furthermore use our communication component of Section IV.B to ensure continuous connectivity in cases where individual networks become unavailable. This is important in particular for mobile scenarios. We also integrated this solution with the endpoint-oriented security component as shown in Section IV.D. With this, we can demonstrate the secure streaming of, say ECG data, from a patient to an emergency response center without connectivity disruption (if alternative connectivity is available, of course).

B. *Insights from User Experiments*

In order to better understand how to design and build systems such as proposed in this paper, we have performed various user-based experiments aimed at giving us more insight into: (1) what information is considered useful; (2) how information should be shown; (3) what interactions should be used. The experiments were both survey-based (online questionnaire) and hands-on. The online survey tested relations between people that reflect on causes for certain important aspects of their wellbeing, such as stress, and their attitude towards systems as described here. The participants were invited through various means (university staff and student mailing lists, Facebook and LinkedIn contacts, PAL project, etc.). As background, we consider participants' experience with self-monitoring systems and their attitude towards self-reflection more important than technological abilities or age.

The results included here are based on 38 participants, 7 with previous experience with self-monitoring, 29 without and 2 that did not specify. The participants were introduced to the preventative part of our demonstrator system from the beginning, through a stress-related usage scenario and a high-level system description. They were asked if they would find such a system useful for self-reflection. Encouragingly, 63% of all participants answered positively. We were particularly interested in how people we considered more self-reflective (i.e., people that think back often *and* think why something happened) feel about the system and 76% said they would find such system useful. Out of the people that answered positively, 74% had no previous experience with self-monitoring systems. Next, we asked if they would like a story-based representation created by the system based on their recorded data (we used a concept movie containing a day story built from events similar to Figure 3). 83.3% of the people that said they would find the system useful said they would like such interface. We also asked if they would like to customise their story. 95% of the ones that like both the system and the story answered positively, with most people wanting to customise characters, places, emotional states, and activities.

We further conducted a series of dedicated experiments with 6 unpaid volunteers (ages between 20 and 80) that aimed at finding out what people consider interesting in their daily activities For that, the users were asked to use digital annotation means we provided (a binary event button on the Alive heart monitor and, later, AIRS-provided phone *widgets:* small interface elements that allow interaction with an application without brining it to the foreground) in order to mark when something they considered interesting enough to be reflected within their lifestyle management system happened or was about to happen.

Essential in understanding how systems like ours should be created is that every user stated that they expect their interest in certain types of information to change within the various situations experienced during the day as well as over time and with increased system usage. Hence, it is expected that the system would provide end users with means to customise their stories over time, both in terms of what they include and in terms of how they look. This would allow them to better understand what could be of interest for them in ways that they have not thought of before. Part of this aspect of *configurability* also includes that each user wants to be in control of what is recorded. Also, being able to change their preferences over time allows a change of focus.

As a result of our experiments we have already added several new features to our system, such as the phone-based widgets used for annotating an event with user's own meaning and another widget that allows users to set their current mood. We consider such features essential for a system like ours, as the automatic inference processes would probably not be able to (always) capture the meaning of why an event was interesting (e.g., is it because the user is in a certain place, or in a certain situation, such as meeting). It is worth noting that users still highlighted the need for faster annotation through dedicated hardware in some scenarios.

VI. CONCLUSIONS AND FUTURE WORK

Pervasive healthcare systems face many real-life deployment challenges that are rarely or poorly addressed. This often leads to disruptions in end user experiences or imposing system constraints, leading to single device or single network solutions. We believe that providing solutions only for bespoke use cases will prevent the wide adoption of healthcare solutions in the future. It is here where our main contribution lies, namely to outline system-wide challenges for healthcare provisioning systems that are addressed through an open, systemic and holistic approach. The resulting PAL system operates over a variety of communication infrastructure solutions. It abstracts the specifics of the infrastructure through a unifying middleware, and is able to support the functional requirements of a wide-range of applications.

At the application-level, we have shown how the lifestyle assistant enables the users of the system to better understand the plethora of available data, by employing novel visualisation approaches that extend detailed graph-based information through story-telling approaches that are engaging and summarising. All of this is achieved within a framework for information governance that takes into account the private and sensitive nature of the information involved. Although our intention is not to build specific diagnostic tools, the lifestyle assistant supports patients in reflecting on their activity history and also assists more formal care processes; thus providing insights for healthcare systems in general.

In our future work, we will investigate the possibilities for conducting detailed studies relating to different aspects of the system, such as visualisation or the security framework. We will also continue to work with funding agencies to incorporate the lessons learned into future system requirements.

ACKNOWLEDGEMENTS

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Development of an e-Healthcare System for University Students

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***Abstract*—An e-Healthcare system with IC card authentication, automatic health screening subsystem and Web-based health information monitoring, has been designed and implemented for university health education. It is a prototype of private Cloud service of e-Healthcare for university students which can obtain their health records from physical measuring devices with their IC card-based authentication, manage their health data in suitable database, investigate such data from viewpoint of doctors/nurses and provide such information for self-healthcare controlling through Web-Database service. This paper presents an organization of the above e-Healthcare system, demonstrates its real usages in university health education and describes its brief evaluation and expanding plan through practical applications.**

Keywords- e-Healthcare; IC card authentication; health screening; health information monitoring; university health education.

I. INTRODUCTION

People of the world have own natural rights to live their healthy lives. They have been interesting in their situations of health and nowadays almost all of them are longing for their healthy environment more strongly than ever before. Doctors always point out that people need to keep their healthy lives if they do not want to be ill and sick. It is very important for everyone to maintain his/her living environment at the healthy level. In other words, everyone wants to have some facilities to monitor his/her healthy level and needs some visualizing tools to recognize whether his/her healthy level becomes good or not.

In every higher education and/or university, even in Japan, of course, its staffs and administration must provide health education and equip health managing environment for its students. Because it is important for current students to study in good condition during their university lives and for external society including their family to welcome the relevant students as its up-and-coming persons. Strictly speaking, however, universities have faced to some problems to be resolved in order to provide efficient health education and they are/have been suffering from the lack of staffs and facilities to manage health keeping environment for their students.

An approach of e-Healthcare seems to be one of the most effective and efficient solutions to improve such environment of health education with the above lack of staffs and facilities in universities as well as in general societies. This approach may be able to provide a powerful strategy to equip so-called “Ubiquitous Healthcare Service” where users can always connect to the information server, monitor their health information in it and obtain suitable advises and instructions for their health management(s).

This paper describes our e-Healthcare system for university students with IC(integrated circuit) card authentication, automatic health screening subsystem and Web-based health information monitoring. First of all, the next (second) section introduces some related works for the sake of comparison and coordination of our study with the state-of-the-art in the same domain. The third section shows configuration of a newly-developed e-Healthcare system and illustrates some details of the system and its facilities. The fourth section demonstrates its real application in our university, explains some brief evaluation of our e-Healthcare system and reports our challenge to expand our system to overground in the future market. Finally, the last (fifth) section concludes our summaries for the perspective study and shows acknowledgements and some useful references.

II. RELATED WORKS

This section introduces some typical related works (papers) in order to compare and coordinate our study with the below the currently and/or previously published papers in the same domain.

A. e-Healthcare related works

B.W. Trevor Rohm of Brigham Young University and his son in [1] described “ Abstract A vision of the e-healthcare era is developed using scenarios from today and for the

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future. The future of e-healthcare is based on empowering individual patients with current information about diagnosis and treatment for personal decision-making about their health without ever visiting a healthcare facility. Empowering the patients is made possible with a futuristic personal medical device (PMD)." And they added "The PMD is a 'black box', which works in conjunction with the internet and locally stores expert system programs. The PMD has various accessories available to help with diagnosis besides voice and image capabilities."

Patrick C. K. Hung from University of Ontario Institute of Technology (UOIT) described in [2] " Information privacy is usually concerned with the confidentiality of personal identifiable information (PII) and protected health information (PHI) such as electronic medical records. Thus, the information access control mechanism for e-Healthcare services must be embedded with privacy-enhancing technologies."

A. Mukherjee and J. McGinnis from Montclair State University categorized and explained 'e-Healthcare' in paper article [3]. And they presented the state-of-the-art to identify key themes in research on e-healthcare. They pointed out " E-healthcare is contributing to the explosive growth within this industry by utilizing the internet and all its capabilities to support its stakeholders with information searches and communication processes. A review of the literature in the marketing and management of e-healthcare was conducted to determine the major themes pertinent to e-healthcare research as well as the commonalities and differences within these themes. Based on the literature review, the five major themes of e-healthcare research identified are: *cost savings*; *virtual networking*; *electronic medical records*; *source credibility and privacy concerns*; and *physician-patient relationships*. E-healthcare systems enable firms to improve efficiency, to reduce costs, and to facilitate the coordination of care across multiple facilities."

B. Ubiquitous Services of e-Healthcare in other related works

Nowadays, e-Healthcare has been tightly connected with ubiquitous computing services. Especially, mobile computing is a key technology to realize e-Healthcare system effectively and efficiently. The below papers are discussing about relations and connections between mobile computing and know-how of construction of e-Healthcare system.

Zhuoqun Li and his supervisors of University of Plymouth described at the relevant conference on Computational Intelligence in Medicine and Healthcare [4] " The growing availability of networked mobile devices has created a vast collective potential of unexploited resources. Grid computing with its model of coordinated resource sharing may provide a way to utilize such resources that are normally distributed throughout a mobile ad-hoc network." They also discussed the general challenges in implementing Grid functionalities (e.g. service discovery, job scheduling and Quality of Service (QoS) provisioning) in the mobile environment and the specific issues had arisen from realistic application scenarios, i.e. the e-healthcare emergency.

Min Chen and his co-researchers of Seoul National University described in [5] " Radio frequency identification technology has received an increasing amount of attention in the past few years as an important emerging technology. To address this challenging issue, we propose an evolution to second-generation RFID (Radio Frequency Identification) systems characterized by the introduction of encoded rules that are dynamically stored in RFID tags. This novel approach facilitates the systems' operation to perform actions on demand for different objects in different situations, and enables improved scalability. Based on 2G-RFID-Sys, we propose a novel e-healthcare management system, and explain how it can be employed to leverage the effectiveness of existing ones. It is foreseeable that the flexibility and scalability of 2G-RFID-Sys will support more automatic and intelligent applications in the future."

C. Design Concept based on Previous Related Works

We have designed our new e-Healthcare system based on not only facing problems to be resolved in our university but also the above previously announced in the public journals and conference papers described in the above subsections. Our design concepts are summarized as follows, the former are our original design concepts introduced from existing problems at the routine physical examination for students in our university. Namely,

- Reduction of time-consuming tasks and frequently occurred human-errors.
- Avoidance of paper-oriented information exchanging and sharing.
- Applicability of newly designed system to Health Education in our university.
- Usage of IC card-based Student Identification for user authentication.

And the latter ones are added through investigation of previous related works in the public papers. Namely,

- Utilization of Mobile Computing technologies including Wireless Local Area Network, 3G/GSM (Global System for Mobile communication) telephone communication and others for position-independent services.
- Employment of suitable "Electronic Medical Records" and/or "Personal Health(care) Records" for seamless healthcare services.
- Capability of newly designed system as so-called Ubiquitous Services or Cloud Services in order to provide effective healthcare environment.

III. Configuration of e-Healthcare System

This section shows configuration of our e-Healthcare system which is already annunciated in the paper [6] and illustrates some details of the system's characteristics and its typical facilities.

A. Configuration of e-Healthcare System

Figure 1 shows a conceptual configuration of our e-Healthcare System in order to resolve existing problems at the

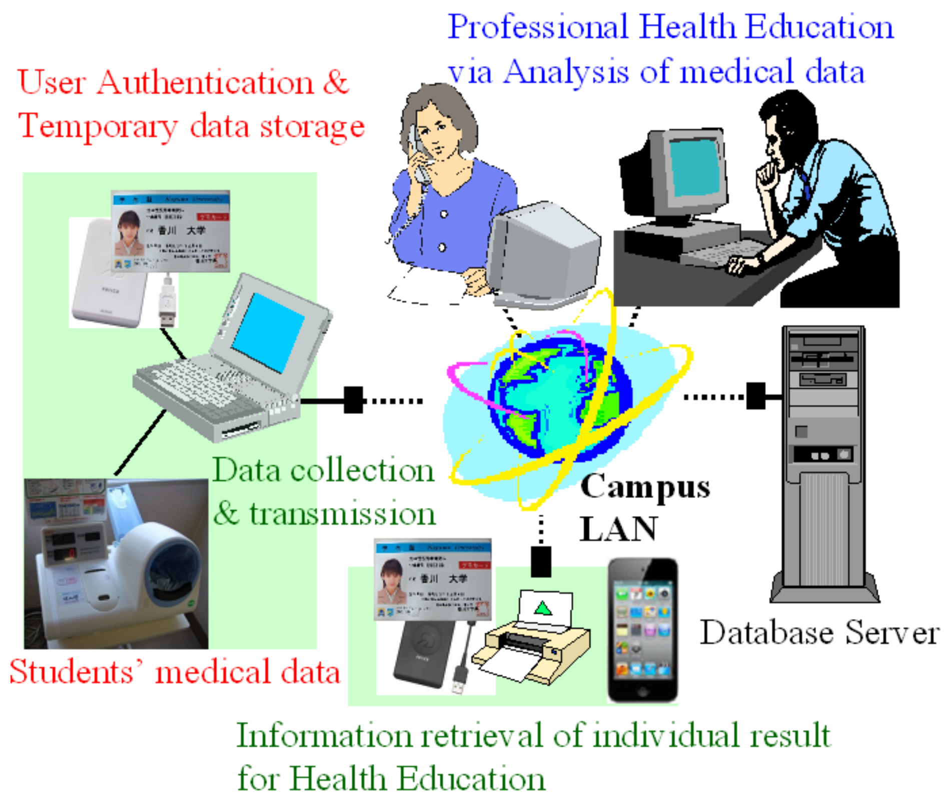

Fig. 1. Conceptual Configuration of an e-Healthcare System (previously annunciated in [6]).

routine physical examination for students in our university. Its characteristics are summarized as follows;

- User(Examinee) authentication with IC card-based student ID for simplification of Examinee checking.
- Automatic data obtaining of physical measuring devices into personal computers in order to reduce time-consuming tasks of paper-based data recording.
- Temporary data storage with IC card for the routine physical examination in not-networked environment.
- Equipment of database for individual healthcare record and health monitoring through campus network.
- Professional health education by university doctors and/or nurses through analysis of medical records from the routine physical examination.
- Information retrieval of medical records from Web-based monitoring with user authentication.

Kart et al. [7] from University of California, Santa Barbara described "Large-scale distributed systems, such as e-healthcare systems, are difficult to develop due to their complex and decentralized nature. With open standards, such as XML [8], SOAP [9], WSDL [10] and UDDI [11], the service oriented architecture supports interoperability between services operating on different platforms and between applications implemented in different programming languages. The service oriented architecture facilitates the development of such systems by supporting modular design, application integration and interoperation, and software reuse." They mentioned in other article [12] of *IT Professional* (March-April 2008) "Medical monitoring devices worn by the patient, and frequent electronic communication between the patient and a nurse, can ensure that the prescribed treatment is being followed and that the patient is making good progress. The e-healthcare system can be readily extended to other healthcare professionals, including medical technicians who perform and report tests and analyses requested by physicians."

Their studies and results have provided some good ideas and comprehensive strategy for us to develop and improve our e-Healthcare system and simultaneously taught us how to select several kinds of technologies for implementation of effective e-Healthcare system for our demand of university. We do not employ such open standards described in the above papers, but we recognize that it is very important to design our system with modular system architecture / programming and utilize standards of protocols and data formats. So our system can have expandability not only to connect with other systems but also to adapt for several kinds of users with interoperability.

B. Sub-systems and facilities of our e-Healthcare System

For example, at first, we introduce a *dedicated sub-system* including physical measuring devices, IC card reader/ writer and personal computer (PC) for controlling. Figure 2 shows a typical *dedicated sub-system* with a blood pressure monitoring device and vision analyzer as physical measuring device.

Controlling PC in Figure 2 has connectivity with the above devices and IC card reader/writer so that user authentication and data acquisition can be realized in the following steps;

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Fig. 2. *Dedicated Sub-system* of Physical Measuring Device, IC card Reader/Writer and Personal Computer.

1) Placing IC card of Examinee on the IC card reader connected to PC.
2) Authenticating ID of Examinee from IC card and obtaining his/her relevant information.
3) Acquiring data from physical measuring device connected to PC.
4) Combining measured data and regarding information of Examinee into the formatted record with time-stamping.
5) Storing the above time-stamped record in IC card if the PC for physical examination is not connected with network environment.
6) Database server can collect such records of PC or IC card into its storage through network environment.

We have already developed a mechanism to build *dedicated sub-systems* in order to interface several measuring devices such as a blood pressure monitoring device, vision analyzer and other devices to take height and weight [13]. So we will be able to expand the above samples into other types of dedicated sub-system relatively easily for other kinds of physical measuring devices.

Secondly, we explain another facility of our e-Healthcare system to realize health monitoring for database server through campus network in university. Figure 3 shows a scheme of health monitoring or health information retrieval for database by university doctor through campus network.

The *dedicated sub-system* of our e-Healthcare system described above can accumulate the formatted record combined with measured data and regarding information of Examinee with time-stamping. So every student (i.e. Examinee) has his/her health records in database with when-where information about the routine physical examination or periodical health checking. Not only the relevant students themselves but also university doctors/nurses can investigate or trace the history/changes of health information in time series.

The relevant facility of our system can generate some kinds of graph based on time-series analysis in order to illustrate the history/changes of health information. Of course, university doctors/nurses can relatively easily perform their professional medical suggestions and/or judgments for some specified students by means of the above facility. Moreover, students will be able to retrieve their health information from database and understand the according history/changes of such information even by themselves.

One of the merits of employing a graphical interface for retrieval of health information is to find out an specific change of health information with irregularity efficiently even at glance. Students can recognize such a case very easily through our e-Healthcare system by themselves and then consult their university doctors and/or nurses with their evidences from our system. Doctors and/or nurses in university also can perform periodical monitoring for graphical retrieving results. They will send some e-mail and other communication to the relevant student about his/her health situation.

With our e-Healthcare system, the above Health Education of university will be introduced and managed effectively and efficiently. The next section will demonstrate its real application in our university, explains some brief evaluation of

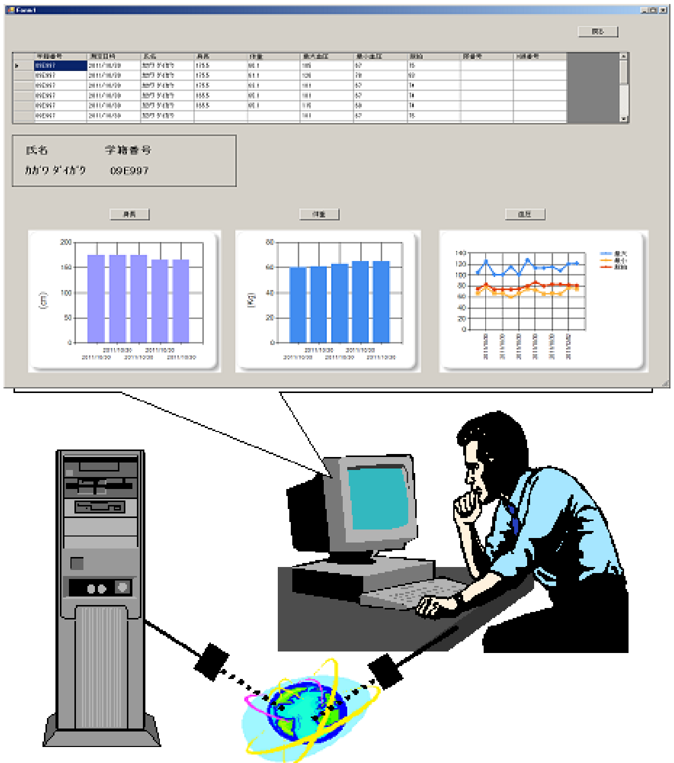

Fig. 3. Health monitoring for Database through campus network.

our e-Healthcare system and reports our challenge to expand our system to overground in the future market.

IV. Application of e-Healthcare System, its Brief Evaluation and its Expanding plan

This section demonstrates real application of our e-Healthcare system at the routine physical examination in our university at first. And then it explains brief evaluation of the system and mentions our new challenge to expand our system for potential market near future.

A. Real Application of e-Healthcare system in the routine physical examination

We have already applied *dedicated sub-system* of our e-Healthcare system described in the previous section to the real routine physical examination since 2011. In the case of Figure 4 , we could not prepare any networked environment for the routine physical examination so that all the *dedicated sub-systems* of our e-Healthcare system had never connected to the campus local area network and the Database information server. Under such condition, our *dedicated sub-systems* must choose the following procedures; namely combining information about IC card of examinee and measured data acquired from the according physical measuring devices and storing such information into the relevant IC card for each examinee during the routine physical examination.

Fig. 4. Photos of the Routine Physical Examination in 2011 with a prototype of our e-Healthcare system.

We call *dedicated sub-system* of our e-Healthcare system “Automatic Health Screening System” for student Health Education in Kagawa University [13]. Figure 5 shows a photo of *dedicated sub-system* of our e-Healthcare system used in the real routine physical examination in 2011. It is configured with Note PC, Physical measuring device (this case shows “blood pressure monitoring device”) and IC card reader/writer. They were connected one another, and measured data had been saved temporally in Note PC as well as each examinee’s IC card. Finally, we had transferred all the data into the information server.

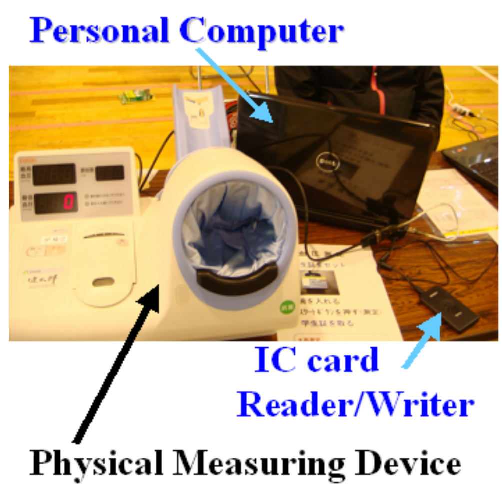

Fig. 5. Photo of a Blood Pressure Monitoring Device as physical measuring device, IC card Reader/Writer and Personal Computer in the routine physical examination.

B. Brief Evaluation and Expanding Plan of e-Healthcare System

From the viewpoint of applying our e-Healthcare system to the real task, the system can provide time-saving operations and precise computation of measuring students’ health information. With our system, our university has enjoyed the above results because the system can reduce total time to perform the routine physical examination and avoid frequently-occurred human errors during physical examination. Our university can also obtain some effects of introducing our e-Healthcare system into practical situation within university tasks which include the routine physical examination and useful Health Education.

Now, we are going to apply for some external budgets in order to bring our e-Healthcare system to the mainstream

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of university-outside. An alliance between university project team and brighter venture company has begun to challenge for national funds for the sake of making our system overground. We must brush up our system into more applicable and more tightly secure one. The former is very important because the system has expandability, while the latter must be unavoidable in the health and medical domains where there are the most values in privacy, security and personal customization. We hope that our e-Healthcare system can be smoothly changed and improved for the above requests from the rising market near future, because it has modularity and expandability introduced in the paper.

V. Conclusion

This paper describes our e-Healthcare system for Student Health Education in Kagawa University. With our system, not only students can receive efficient Health Education but also doctors/nurses can provide fruitful medical suggestion and/or judgment through health monitoring. The routine physical examination can be improved into reduction of time-consuming tasks as well as avoidance of frequently-occurred human errors.

Characteristics of our e-Healthcare system are summarized as follows;

- Employment of modular system architecture for easy maintenance, effective interoperability and system expandability:
  Our e-Healthcare system includes a *dedicated sub-system* with some kinds of physical measuring devices, IC card reader/writer and controlling PC(s), a Database information server and some facilities for user-side health monitoring and retrieving. Each *dedicated sub-system* can be relatively easily tailored for other kinds of physical measuring devices. An additional facility can be built into the system for the sake of system expansion.
- Utilization of student IC card for user identification:
  It is a good idea to employ student IC card for user(i.e. examinee) identification during physical examination. With such IC card-based identification, our e-healthcare system can reduce and shorten total mount of time to register and authenticate examinees for physical screening test.
- Realization of mechanism to interface between measuring devices and computers:
  In order to build some kinds of interfaces between physical measuring devices and controlling PC in *dedicated sub-system*, it must be done to connect device into computer's Input-Output ports such as USB(Universal Serial Bus interface), write specific software for interrupts just like drivers and manipulate such devices by the controlling PC. With automatic control of measuring devices by such PC, our e-Healthcare system can avoid probabilistically happened human errors as well as writing mistake of measured data.
- Visualization of history/changes of health information in time series:
  The specific facility of our system can generate graphic information based on time-series analysis in order to illustrate the history/changes of health information. Doctors/nurses of university can relatively easily perform their professional medical suggestions and/or judgments by means of such a facility. Students can also recognize graphical history/changes of their health information.

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Chronic Disease Management System Based on eHealth Concept in China

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***Abstract*—Chronic diseases have posed great threats for the health of the residents in China. The treatments for chronic diseases usually endure a long time. Therefore, a lot of medical resources are occupied. In this article, we introduce the chronic diseases management system (CDMS) based on eHealth concept. Patients can detect the index relevant to the chronic diseases by themselves and get some instructive guides about health-care from this system. The application of this management system will enhance the patients' awareness of diseases and thereby lower the expenses of the treatments for chronic diseases.**

Keywords-chronic disease; PHR; eHealth.

I. INTRODUCTION

The incidences of chronic diseases are increasing with the improving of living standard and the changing of eating habit. Chronic diseases occur in young age gradually. In China, chronic diseases have been the main causes of death. As the statistics of the year 2000 showed that 80.9% of mortality was attributed to chronic diseases [1]. Furthermore, chronic diseases will greatly affect the life quality of the aged. Take Shanghai, for example, 73.76% residents developed chronic diseases among the aged in 2008.

Chronic disease, usually, has a long course and is hard to be cured. The interventions and treatments for the patients are important. The Internet of Things (IoT) is a concept that describes how the Internet is being used to link consumer devices and physical assets so that these new endpoints can create and receive a data stream. The method based on IoT will realize the purpose of remote monitoring for the susceptible population and patients.

In this paper, we introduce a chronic disease management system (CDMS) based on eHealth. This system can not only monitor the vital signs of the patients through long distance for the benefit of telemedicine, but also help to arouse the awareness of the health statues for the patients. Compared to the traditional telemedicine systems, the CDMS is more focused on attracting the patients to participate in self-health management. Due to the use of a service component architecture technology, components of the system can run independently to provide web services. The components do not interference each other which makes it convenient for function expansion.

In Section II, we give a brief architecture overview of the CDMS. More details of the CDMS's components are described in Section III to Section VII. Two main features, Front-end Data Cleaning and User-friendly System, are introduced in Section VIII. An example of using the CDMS is given in Section IX. Finally, we drew a conclusion in Section X.

II. CDMS'S ARCHITECTURE

There are always new chronic diseases will be found, and chronic diseases prevention and control methods may change over time. We cannot design a common mode to manage all of the chronic diseases. In order to overcome the uncertainty, the chronic diseases management system (CDMS) should be flexible enough to change the chronic diseases prevention and control methods and scalable enough to manage the new chronic diseases.

The CDMS took SOA (Service-Oriented Architecture) as the main architecture to ensure the system's flexibility and scalability. A Service-Oriented Architecture (SOA) [2] is a set of principles and methodologies for designing and developing software in the form of interoperable services, and the services are unassociated, loosely coupled units of functionality. By SOA, the CDMS can easily add new services to manage new chronic diseases and replace old services to change chronic diseases prevention and control methods.

The system architecture is shown in Figure 1. All components in the system communicate with each other by web service (WS), so each component can evolve respectively according to the different needs and will not affect each other. The components on the upper part of the picture are system-specific components and need to be developed. The others on the lower half are common components, which have the corresponding software implementations.

The system-specific components include the five components of Personal Health Records (PHR), Drug Database, Evidence-based Medicine, Chronic Disease Management Service, Vital Signs Integration Service; we will introduce them in later sections, respectively. Chronic Disease Management Portal is the portal of the CDMS and users can access all components through it.

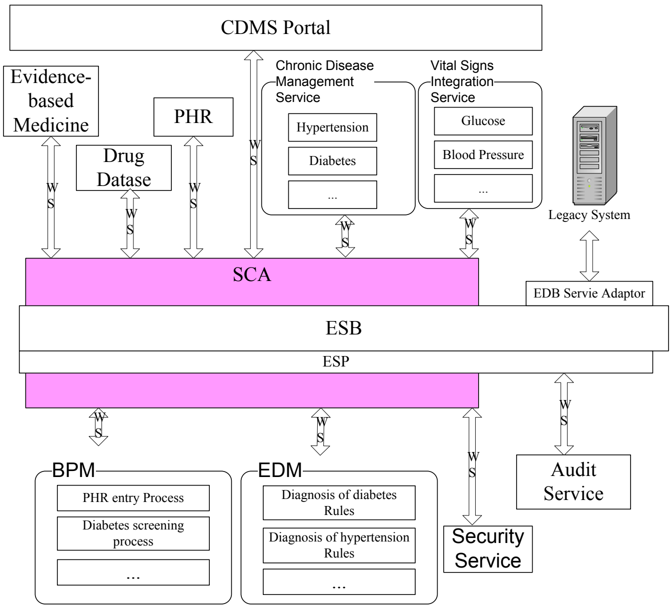

Figure 1. CDMS's architecture

The common components include Enterprise Service Bus (ESB), Event Stream Processing (ESP), Service Component Architecture (SCA), Business Process Management (BPM), Enterprise Decision Management (EDM), and each of the five components has corresponding open source implementations. The CDMS just selects and integrates the implementations by SOA.

ESB, ESP and SCA are the basis of the CDMS. ESB can be used to integrate legacy services or applications (such as HIS, PACS, etc.). By using ESB, the CDMS does not need to repeat patient data entry, which had existed in the legacy systems. ESP enables the CDMS to monitor multiple streams of event data, and analyze them. Normally, ESB is used to audit the accounts in the CDMS. Services are core to SOA. Using SCA, you can build units of functionality, or components, supporting a variety of languages, and then expose them as services over protocols. Moreover, these components can be wired together internally to form higher-level services, or composites. And the services can run in a distributed fashion and be managed as a virtual cloud. By SCA, the CDMS can add more services to manage new chronic diseases easily.

BPM and EDM are used to design visually chronic disease management processes and medical decision-making that can be used to the CDMS immediately. Because visual designers are provided by BPM and EDM, doctors can also design the processes and decision-makings easily. In this way, the CDMS can attract the doctors to participate the design of the system.

III. PERSONAL HEALTH RECORDS (PHR)

Chronic diseases are diseases of long duration and generally slow progression. The prevention and treatment of chronic diseases relies mainly on the patients' own efforts, including developing good living and eating habits, taking medicine on time, etc. In order to store all of the patient-centered data, the CDMS use PHR as the underlying data model.

A personal health record is a collection of health-related information that is documented and maintained by the individual it pertains to. By using PHR, the CDMS allows patients to participate in their own healthcare management by viewing, editing, or discussing their own medical data.

Internationally, several institutions and organizations are concerned with standardization of EHR (Electronic Health Records) [3][4], and some of the standards such as openEHR [5], HL7 CDA [6], CEN 13606 can be used to build the PHR. Compared with other standards, the openEHR is more generic, particularly due to being archetype-driven, and can satisfies many requirements outside the original concept of the "clinical EHR". After our research, we believe that openEHR is best suited to build the PHR model in the CDMS.

But, openEHR only given the definition of the basic structure of PHR, and you need to define the PHR items on your own. In 2009, Ministry of Health of the People's Republic of China published the basic framework and data standard of the health records (China HR) [7]. The standard has defined the minimum collection of health record data items. Therefore, by combining the standard with openEHR, we can define the PHR which is applicable to China.

The openEHR EHR is structured according to a relatively simple model. A central HER object identified by an EHR id specifies references to a number of types of structured, versioned information [5]. According to the definition of the EHR object, compositions are the containers of all clinical and administrative content of the record. In one HER there are two general categories of compositions: event compositions, and longitudinal, or persistent compositions. To add China HR data items into the compositions, we should divide the items into instantaneous information (corresponding to the EVENT composition) and long-term information (corresponding to the PERSITION composition). The items about basic personal information are different from others and are separated as a special component.

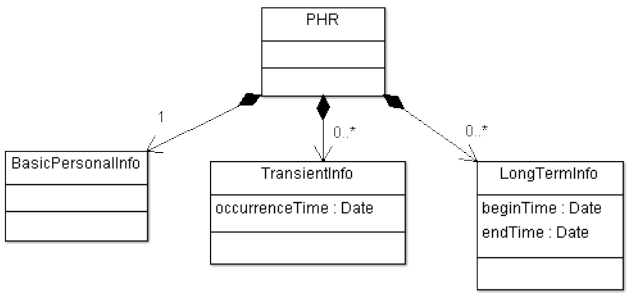

Figure 2. PHR basic structure

The basic structure of the PHR in the CDMS is shown in Figure 2. The PHR object is the root object, which contains all health information of a patient. The BasicPersonalInfo object records the patient's basic information, for example, name, age, gender etc. The TransientInfo object is used to record instantaneous information like clinical testing. The LongTermInfo is used to record long-term information like medication records.

IV. DRUG DATABASE

Drug database plays an important role in chronic disease management. All the precise information of a drug is included in this database. The application of this database is to give patients some advices on rational drug use according to their drug use history.

The Drug database component is more general than the other components of the CDMS. In addition to information of drugs for chronic, the component also includes other drugs' information. In the future, the component will be extracted as an independent service application.

We selected more than 2000 drugs and structuralized their information. As the displaying mode is based on web service, we can add more information (such as drug target, drug interaction) into the database later on. We aim to serve for the personalized medicine.

V. VITAL SIGNS INTEGRATION SERVICE (VSIS)

In the CDMS, timely access to the signs information of high-risk groups or patients is of great help for chronic disease prevention and control.

With the development of the Internet of Things technology, through wireless transmission technology, to achieve real-time remote vital signs collection, has become possible and inexpensive.

The schematic diagram of the vital signs integration in the CDMS shows in Figure 3.

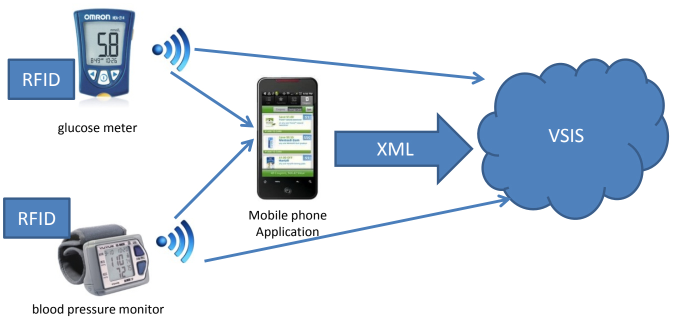

Figure 3. Vital signs integration schematic

All sensors (such as blood pressure monitors, glucose meters) in the figure contain RFID reader devices and wireless transmission module. RFID reader devices are used to identify users. The wireless transmission module is used for data transmission, including two ways of transmission: one way transmits data via Bluetooth to mobile phone, then transmits data to a back-end server; the other way transmits data directly to the servers via GPRS.

The mobile phone application is the core of the entire integration module for signs sensor, it can pre-process the data transmitted by the sensor, also allow users to view the data. At the same time, when the server side have done further analysis of the data, the application can be used to receive the analysis results.

The VSIS provides RESTful WS (the Web Service by Representational State Transfer) to collect data from mobile phones. The transmission between it and the cell phone uses XML as a data interchange format. It does not compel to limit the sensor must be output in XML data format because of the diversity of sensors. If the data generated by the sensors is not XML format, it will be converted through the Enterprise Service Bus configured on a particular service adapter, and then transmitted to the VSIS.

VI. EVIDENCE-BASED MEDICINE

Evidence-based medicine (EBM) aims to apply the best available evidence gained from the scientific method to clinical decision making. It seeks to assess the strength of the evidence of risks and benefits of treatments (including lack of treatment) and diagnostic tests. This helps clinicians understand whether or not a treatment will do more good than harm.

Some useful and helpful evidence-based medicine databases (such as Cochrane, MD Consult) have been widely used through the world. We utilize this idea in our database designing.

Take Hypertension, for instance. We collected some strong evidences from massive publications and integrated them into our system. When a patient refers to the suggestion about "eating habit", the system will come up with the latest evidences on "how to eat healthily as a hypertension patient". We help the patients to manage their health condition and educate themselves about the knowledge of disease.

VII. CHRONIC DISEASE MANAGEMENT SERVICE

Chronic disease management service component is used to manage all chronic diseases. Because every chronic disease haves different day-to-day management process, it is need to develop different sub component. Although different chronic disease needs to develop different sub component, other components of the CDMS that all chronic disease management service's sub components need to call are the same. The disease-related vital signs are provided by the VSIS component, the data used for clinics analysis is provided by the PHR component, the recommended or warning information about patients taking medicines is from the drug database component and some of the latest chronic disease educational information is provided by the evidence-based medicine component.

In order to ensure the flexibility of the system, the management processes in chronic disease management service are provided by the BPM component. Its advantage is that, if you need to make changes to certain chronic disease management process, you can just change the related management processes in the BPM component. And the chronic disease management service component uses rules of the EDM component to diagnose and treat chronic diseases. The EDM component allows doctors to design the rules by themselves.

VIII. SYSTEM FEATURES

The CDMS is designed to help the patients with chronic diseases to participate in self-health management, and improve their health status while reducing hospitalization.

To achieve this goal, the CDMS should encourage patients to detect vital signs themselves. However, this will lead to more erroneous data are submitted into the CDMS. To overcome the problem, a data-cleaning framework named Front-end Data Cleaning is introduced.

Meanwhile, in order to attract patients to use the system, The CDMS should be user-friendly, which means that the system should be easy to access, the contents provided by the system should be easy to understand.

The two main features will be introduced in this chapter.

A. Front-end Data Cleaning

The VSIS module is normally used to collect patients' own detected vital signs. The biggest problem in the module is to ensure the accuracy of the data submitted by patients. To solve the problem, a simple framework for data cleaning is designed. The framework includes two parts. The first part is a filter to check abnormal data outside the confidence interval and alert the user. If the user confirms the accuracy of the data, the data can be stored in the system and be used to amend the confidence interval. The second part is a calculation module that calculates the confidence interval by the patient's historical data (including the data submitted by the filter). The filter locates in the mobile phone or the sensor, and the calculation module is embedded in the VSIS.

Using the framework, the CDMS can filter a lot of erroneous data in front-end devices. Of course, different vital signs require different algorithms to calculate confidence intervals.

B. User-friendly System

The CDMS Portal lets users to access the CDMS through web browsers. Meanwhile users can also access the CDMS by mobile phone. The VSIS module uses a mobile phone application to collect patients' vital signs. In fact, the application also allows users to access the CDMS. The application can synchronize data with the CDMS while it is online and analysis data offline. In this way users can access the CDMS anywhere anytime.

To let users more easily understood expertise of chronic diseases, the CDMS should promptly adjust the contents in the CDMS by users' feedback. This means the CDMS should be easier to be modified and extended than other traditional medical information systems. Thanks to the SOA technology, the CDSM can meet this demand easily.

IX. EXAMPLE-- MANAGEMENT OF HYPERTENSION

So far, a hypertension management module has been implemented in the CDMS. In this chapter, we will look at how users use the CDMS to manage their hypertension.

When a patient gets a blood pressure monitor and registers for an account, he can use the CDMS. First of all, he should enter his basic information, such as age, gender, blood pressure value, medication information, etc.

Now, he can get the system's help to manage his hypertension. Usually the system will remind him to measure blood pressure and take medicines regularly. When the system detects the abnormal blood pressure values, it will alert him. If this situation continues for several days, the system will notify the doctor to contact him.

X. CONCLUSION

This article describes the design of SOA-based architecture chronic disease management system, the infrastructure of the system using existing SOA technology, and on this basis, develops a service component in the management of chronic disease. Various components interact through web service, evolve independently and will not affect each other. The VSIS component makes full use of existing Internet of Things technology, having the function of remote collection of the user's vital signs, allowing users to keep abreast of their own health, also providing support for the remote diagnosis and treatment from doctors. In order to allow users to get the latest medical research, we developed the component of evidence-based medicine to provide intelligible results of the latest evidence-based medicine. And other components are developed on the purpose of providing effective services to the patients having chronic disease.

However, the current chronic disease management system still has many aspects to be perfected. In PHR component, data structure has not yet fully established, the next work will further improve in this area. In EDM component, we are still unable to provide a language that doctors can directly use to design diagnosis and treatment rules. In the future, we will combine the expertise of medical personnel to create a language in related field, facilitating the use of medical workers.

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Enhanced Home-Based Medical Care Services Through Mobile Technology

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***Abstract* — One of the fastest emerging services in healthcare is the development of home-based or home-based healthcare services. This trend has been growing in Europe, North America and Australia, especially in the last five years. However, the major challenge is the monitoring and control of the quality of the service. In this paper, we propose a set of procedures for the quality control and monitoring of the service delivered, with the workflow being streamlined using mobile technology. The proposed model was simulated on different service management models and proved an assured tendency for an accurate tracking of the practice. Simulations revealed that upon the application of these procedures up to 70 % (i.e. if 70 % of recommendations are applied), 90% of common medical errors could be avoided. In the proposed model, patients (under well defined mental conditions) are evoked and encouraged to constitute a part of the control procedure. The awareness of the patient reduces the estimated error measurement largely. The model takes care also of the quality control of certain medical devices (portable diagnostic devices) that are usually used in such practices.**

Keywords-quality control; home-based care; mobile technology; total quality management; healthcare management.

I. INTRODUCTION

Many years ago, people used to have medical care provided at their places, where “physicians” used to diagnose and treat patients at their homes. This constituted an important opportunity for the physician to take a live look at the patient’s living conditions, given that these conditions were considered by that time as the most possible causes for diseases.

With the development of medical equipment and tools for both diagnosis and therapy, there was a need to gather all these equipment in a place (Hospital) where patients could come to have medical services administered. This constituted an important step in the control of diseases especially contagious ones. With such a measure, people living with the patient were no longer endangered or subjected to the disease.

As hospitals widely spread all over the world, an important issue unfolded: infection and its control. Most of the hospitals worldwide are general hospitals, which render them as places gathering a huge number of patients having different diseases, mostly infections. This leads to anticipate that a hospital is a place where we can –with a high probability– contract an infection (nosocomial infection). In order to minimize the aforementioned risk, many procedures and techniques were developed [1, 2]. One of the most common measures is to minimize the period of stay of the patient at the hospital [3]. Usually, patients having surgery procedures who are not in need for concentrated or intensive care can stay for a number of days at the hospital for the ordinary nursing tasks. During his/her stay, the patient is subjected to a non-negligible risk of infection. In cases where ordinary tasks could be performed at home, it would be better if the patient receives such a service at his/her own place. This will decrease the infection risk, liberate more space at the hospital, and in most of cases decrease the cost of treatment [4].

The development of home-based care services is widely spreading in Europe and in the United States. The services mostly ensure medical and logistic help for seniors, children with special needs, persons suffering from chronic diseases. Late studies have revealed that even some cancer cases can be followed home-based [5, 6, 7].

However, many problems are ensuing with the growth of this trend [8], the major amongst which is the lack of control of the nurse or staff delivering the service, when there is no direct supervision, as is the case in a hospital setting! In the latter case, the medical personnel are usually supervised at two levels (nurse / staff nurse and staff nurse / physician). Sometimes, a floor or ward supervisor can be added to the chain, just prior to the physician level. In this work, we will be focusing on the issues related to quality control and the quality assurance of the service. In hospitals, the staff follows well-defined and well-practiced procedures to perform daily tasks. In addition, the presence of a staff nurse or any other well-experienced staff who can ensure that technical support is available when needed decreases the risk of errors. This is not the case when it comes to home-based care services. Entities delivering these services are mostly private and they are governed by budgetary and human resources limitations. Thus, in most cases, they tend to minimize the personnel servicing one person at the time (depending of the case). The human resources limitations

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may sometimes lead to employ some staff without enough experience. At this stage, a weakness point is identified which can be restated as follows: Lack of control on – and support (technical) for – the staff performing the medical task [9].

In 2006, Koch [10] summarized the state of research on home-based healthcare from an international perspective. In their study, they reviewed all scientific literature concerned with telehealth services between 1990 and 2003. They observed a trend towards tools and services, not only for professionals, but also for patients and citizens. It could be noticed that it was difficult to determine the quality of care in the presented solutions. They stated mainly the lack of standards for the compatibility of information systems, as well as the lack of evaluation frameworks considering legal, ethical, organizational, clinical, usability and technical aspects. Added to that comes the lack of proper guidelines for practical implementation of home-based healthcare solutions. [10]

Recently, Kuo *et al.* [11] developed an information technology (IT)-mediated home-based healthcare model designed to improve the effectiveness of caring for stroke patients who require chronic home care. The developed model showed an important success; however, their system depended on a measurement device capable of monitoring certain physiologic parameters and sending them to a control room. Such dependence posed as a major limitation to the model.

Margolis and co-workers presented a design and rationale for home blood pressure telemonitoring and case management to control hypertension with a cluster randomized trial [12]. The system communicates the measurements of blood pressure to a control space, without taking into account the quality of measurement.

In this paper, we propose a general control model that can be used to evaluate the quality of home-based care services. The model responds to the weakness points identified above; thus, the basic idea behind it is to ensure proper control and support for the staff, and to involve the patient in such a process. It conforms to the basics of total quality management – in general – and quality healthcare management in particular. The pillar in the proposed monitoring system is mobile technology, where the patient, the nurse, the physician, and the hospital information system are all linked in real-time.

After this introduction, the problem is detailed and laid down. The solution is then featured and characterized. Finally, future perspectives and possible ameliorations of the system are pointed out.

II. SITUATIONAL ANALYSIS

Controlling the quality of a service involves many parameters that should be evaluated and reported by the person delivering the service. Thus, it is tightly linked to the auto diagnosis methodology of the person and the system together. The identification of the problem causes reveals important aspects, as depicted in Figure 1.

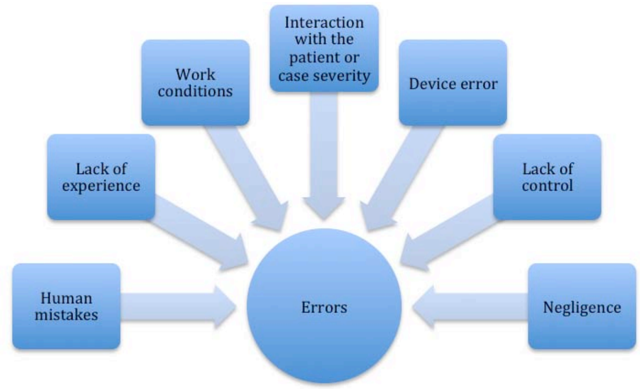

Figure 1. Roots of error.

Figure 1 shows the possible causes of error according to a deep literature research on common errors in similar cases. The query included reported cases, patient surveys, and literature works. A simulation was performed in order to define an interval for each type of error according to the other parameters.

The lack of experience was used as a testing parameter. This parameter is studied in two cases under conditions with and without control from a superior. A representation of the total error in both cases is presented in Figure 2.

The above demonstration shows the importance of the control for many reasons. Thus, a primary parameter is identified that leads to have an oversight on the staff on a permanent manner. Here, we should mention that the presence of a control mechanism or a "*permanent assistance*" as we will call it later not only provides the control but also ensures a live support in case of need for information or in any emergency situation.

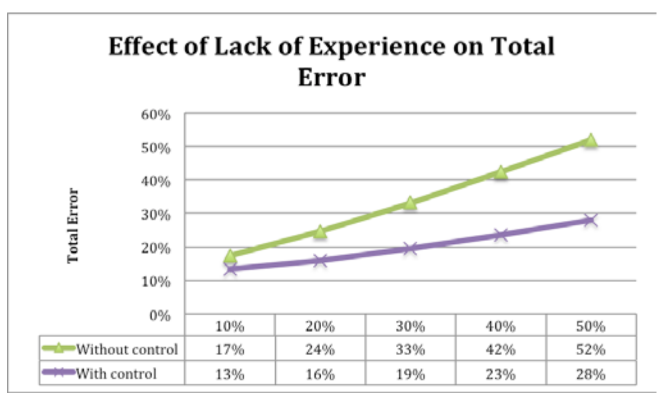

Figure 2. Total error in both cases with and without control.

One important issue can be revealed which is the importance of having a mechanism for archiving and analysis for all events that occur through the treatment process. Home-based care services are new enough that it is too difficult to find databases containing statistics or archives for incidents taking place. The presence of such databases minimizes the probability of mistake occurrence. Thus, the lack of supportive data is identified as an additional weakness point.

The two points identified show the contribution of the staff to dealing with errors; however, an important factor is added which is the interaction of the patient himself/herself. For example, a hospitalized patient who is prevented from smoking for dangerous consequences will not be able to smoke in a hospital, but this is not the case for those patients receiving care at home. The interaction and responsiveness of patients receiving home-based care services constitute a difficult challenge in the treatment process. This point will be considered as a constraint in the solution process.

Another constraint is the living environment of the patient and the respect of healthy living conditions at home. A sick person is more susceptible for infections than a normal one, which imposes giving high attention to hygiene control and to the quality of ambient air and temperature in the living place of the patient. This in turn reflects another challenge for treatment process because it depends relatively on the financial conditions of the patient.

Figure 3 summarizes the different weaknesses and constraints of the treatment process and the cause-effect relationship between each of the contributors. As presented in the figure, there are many parameters that influence the treatment process and are considered as limiting aspects. Besides, the quality control of the medical equipment used should eventually be addressed in some cases. For instance, a non-stable blood pressure measurement device can provoke a lot of disturbance for a non-experienced staff who may not doubt the measured value and further investigate it. Troubles and panic evoked by non-controlled or non-maintained devices can lead to dangerous decisions in certain cases ultimately increasing risk. Such a probability of errors in portable medical equipment may be higher because such devices are usually kept either with the staff or at the patient's place. In a hospital, medical devices are usually maintained almost on a daily basis and the availability of a biomedical engineer or a technician on site decreases the risk. The biomedical department in a hospital performs periodic checks on the functioning conditions of devices (humidity, temperature, electricity and grounding, electric safety, etc.). In home-based care, neither the staff nor the patient are trained or qualified to perform such a task.

Figure 3. Cause-effect relationship influencing the treatment process in home-based healthcare.

III. Model and Management of the Solution

A. *Controls and Support*

The proposed management model for the service contains steps and procedures in order to minimize the risk and errors provoked by each of the above-mentioned issues. The model is based on the use of information and communication technology facilities in order to maintain acceptable working conditions, thus improving the quality of the service delivered.

Nowadays, portable touchpads and smart devices can establish a bidirectional communication process where data is transferred rapidly and processed in a very short time. The design involves pre-defined mobile devices that connect through a secure application to a central system/database hosted at the hospital or at the company offering the service.

The mobile application, installed on a mobile smart device (Touchpads, tablet PCs, smart phones, etc.) will have two different versions; one for the patient, and another for the physician. The mobile application can be modified or adapted depending on the case requirements that are defined through a well-traced procedure.

The goal of the application will be:

Physician's version:
1-Send instructions to the control room.
2-Establish communication between the physician and the patient at home.
3-Show critical medical information of patients (patient's file, medical measurements, etc…)
4-Show needed reports/trends about patients
5-Receive emergency reports/alarms from the system

Patient's version:
1-Send medical readings/measurements to the control room (example: blood pressure measurements).
2-Establish communication between physician and patient.
3-Receive instructions/alarms from control room.

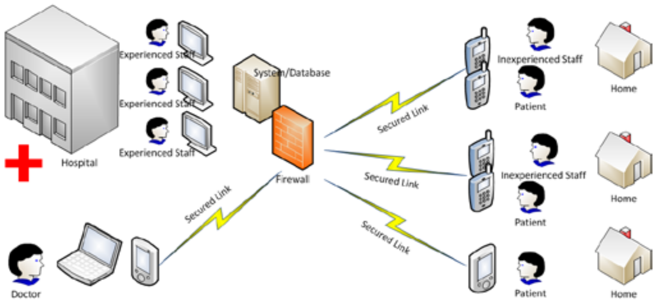

Figure 4. Home-based care system sample diagram.

In the control room, the system will be managed by the experienced staff member(s) to control and manage the communication processes between the control room, patients, and physicians; as well as follow the treatment processes between the staff and the treating physician who may be situated inside or outside the hospital.

The system itself will:
1- Collect medical readings from patients.
2- Collect instructions from physicians.
3- Host maintenance information about mobile medical equipment.
4- Ensure on-time connectivity to mobile devices.
5- Analyze data based on intelligence.
6- Trigger alarms

A sample diagram of the system is illustrated in Figure 4.

The created mobile application contains multiple steps where at the end of each routine to be performed by the staff, an outcome is required. The outcome will be presented as a value to be entered by the staff/patient. The value entered is transferred directly and shown on the server's screen in the 'Central Control Room". The transfer of data to the control room enables online verification by the control room officer. The importance of this step comes from the fact that the control room officer, who in turn ensures the technical support and the control for the staff, can verify any procedure. A screenshot of what is displayed to the staff is shown in Figure 5.

Figure 5. Screenshots of the mobile application. An example of the initial pad navigation screen (left) showing two potential patients. A summary of a measurement (blood pressure in this case) is shown to the right.

The software enables to create a visible history of any parameter of the patient. This history can be connected with the control room directly. This can even be done through videoconferencing, where the control room officer can in turn talk to the patient.

Transferring the information all the time to the control room permits to create huge databases where all events are added using neural archiving methodologies. This data can ensure an important support for the staff and builds an expert system that will always be available in case it is needed. A key bonus of this feature is traceability, where all events are recorded along with respective timestamps.

B. *Patient Responsiveness and Awareness*

Improving patient responsiveness and awareness has been shown to increase when patients are involved in the treatment process. A developed version of the model and the application proposes that two touch devices be used, where one of them will be kept with the patient. On the patient's device, a patient application is installed permitting the interaction and the communication with the control room and with the staff concerned if available. In her/his dedicated application, the patient will be asked to enter all the parameters measured by the staff as the latter does on his/her own application. The staff will be asked to approve the data entered by the patient through the mobile application. Some alerts are programmed so that when a measured value approaches the safety limits or thresholds, a sign attracting the patient's attention is launched. However, this should be applied in a limited number of cases, depending on the patient's alertness and/or – probably – their psychological aptitude. Such a dual system is exemplified in Figure 6.

Besides alerting the patient and involving her/him in the process, another purpose of having the data entered by the patient is to have a second reading of the parameter to be measured. This minimizes the risk of the human error and allows the staff to have a second look at the measured value.

Certain features for the entertainment of patients might be incorporated in the application thus improving the healing process. A psychic follow up can be also ensured through this application.

C. *Patient Living Conditions*

In the proposed model, a primary step is added to the patient incorporation procedure. This step is to perform an evaluation for the patient's living place at the very beginning of the treatment process. If the patient's living conditions are not adequate, the service might not be offered and the patient will be kept at the hospital. Eventually, some modifications might be required so that the living place stays in conformity with the defined norms. This can lead to

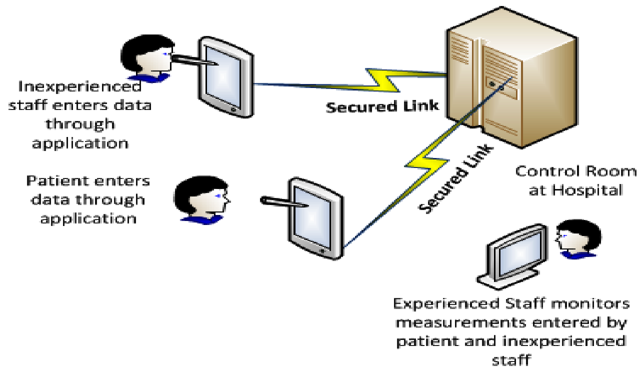

Figure 6. Communication scheme between the various key players.

the identification of some parameters that will be added to the mobile application and measured on an hourly, daily, or weekly basis depending on the parameter.

D. Devices Maintenance

In the dedicated program, a tab is designated for the device history. For any measured parameter, the application will ask the staff to enter the tag number of the device used. The tag number is an identification code that permits the system to check in the database for the device history. In the device history, all device maintenance records and control data are archived. The staff will be alerted if the device was not maintained or checked on time. In addition, when an abnormal value is measured, the system will directly check the maintenance date, and it might ask the staff to perform the test once or more, as shown in Figure 7.

IV. Conclusions and Perspectives

As home-based medical services are becoming a reality in today's society, innovative solutions are needed to help offer such services safely and efficiently. Technology plays an important role in ensuring this and in guaranteeing the quality of offered service. This is all the more so when the services are rendered in a country that markets itself as a destination for health tourism [13]. The proposed model enhances the home-based care service in a rapid and non-expensive manner taking into account key quality considerations. The preliminary implementation of the system – in cooperation with a Lebanese private hospital and a one-day-surgery polyclinic – involved the collection of data comprising vital signs (body temperature, blood pressure, pulse rate), blood glucose, general appearance, and – in limited cases – urination frequency and volume. The collected data produced seed information that was further used to extrapolate into more quasi-real settings. Current raw data (not shown) is in complete accord with the proposed model based on the simulation data shown above.

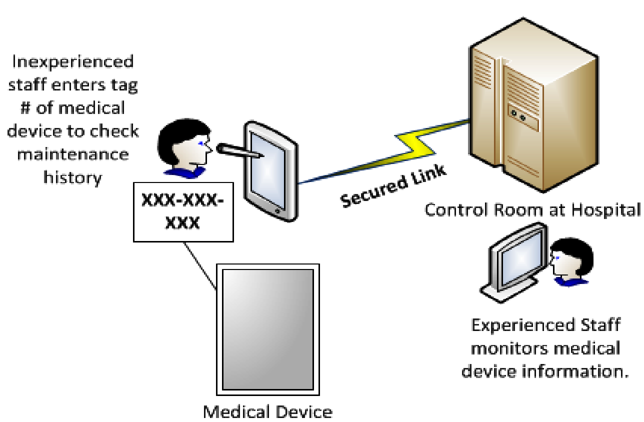

Figure 7. Equipment maintenance tracking system.

The use of information and mobile communication technology permits the instantaneous control and support of the medical services rendered at home. Future advanced versions of the application may contain more features designed for people with special needs so that a permanent assistance is ensured. Other features may include tracking of the staff and patients, probably through the usage of global positioning system (GPS) capabilities in the device and an active subscription-based service to broadcast geographical locations. Both technical and geographical tracking can be performed at the same time through this software-based model.

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Heath Kiosks as an Equal Opportunity Resource for Better Health: A Systematic Review

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Abstract— **Computerized health kiosk systems could be the key to improving public health among diverse populations around the world. The objective of our study is to examine the current utilization of health kiosks in various diverse settings. Further, the study aims to describe the various characteristics of the individuals using these health kiosks. A search was performed using a scientific database, Pubmed, to identify articles published during the period of January 2005 to January 2012 using the following keywords: "public health kiosk", "public health kiosk rural", and "public health kiosk urban". A secondary search was also performed to include the articles that met the inclusion criteria. Results of our review show variations in the geographic patterns of users' accessibility of kiosk locations. Health kiosk acceptance was high among Black Hispanics, people born outside of the United States, and users with no formal education past high school. High satisfaction was observed among low literacy users, individuals with no formal education, and low-income families. Older populations accessed kiosks at churches and health fairs. Users with no insurance most commonly accessed the kiosk at public libraries, followed by neighborhood health centers and Laundromats. The health kiosks have shown to be a useful medium of reducing health disparities by bridging the gap among users with varied characteristics. However, there is a need for further research to determine long-term impacts of health kiosks on the health outcomes of the populations in various settings.**

Keywords- Health kiosks; users; technology; acceptance.

I. INTRODUCTION

Computerized kiosk systems could be the key to improving public health around the world among diverse populations. Public health kiosks have proved to be successful in disseminating health education and interventions. Kiosks are free standing units containing a computer that delivers services, as well as informational and instrumental support. Many of the kiosk computers have touch-screen interfaces and vary in the level of interactivity. Public kiosks have been used in the distribution of a variety of services, such as gift registries, bank Automatic Teller Machines (ATMs), movie theater tickets, movie rentals, and grocery store checkout lanes. The current utilization of kiosk systems has made the use of health kiosks accepted and familiar in public settings. Conventional ways of delivering health interventions to participants would be time and labor extensive to provide tailor health information for each participant of the health intervention. The health kiosk improves the quality of information appropriate to the user across a larger, more diverse audience. Therefore, health kiosks are time efficient, accessible, and have the capability of adapting to diversity [1]-[3].

Culture, socioeconomic status, and language are three components that affect the gap of health disparities. Health care delivery should be culturally competent for at least six reasons: (1) respond to demographic changes, (2) improve quality of services and health outcomes, (3) meet legislative, regulatory and accreditation mandates, (4) gain a competitive edge in the market place, (5) decrease liability and malpractice claims, and (6) eliminate health disparities of diverse cultural, ethnic, and racial backgrounds [3]. Programs have been designed through conducting surveys within communities enabling them to present consistent culturally relevant information that has been approved by individuals in the community [5]. Furthermore, providing relevant information itself can help reduce disparities within populations, and help close the gap of low health literacy. Cultural tailoring and theoretical framework needs to be incorporated in the delivery of health information, and can be easily managed into the design of kiosk programs. Kiosks have the ability to provide multiple language options in the delivery health information, and maintain consistent culturally relevant information.

Public health promotion efforts would be more successful if they were targeted at specific geographic areas. The national public health objective calls for an increased use of Geographic Information Systems (GIS) to make interventions more cost effective [6]. The use of GIS can improve health promotion and disease prevention efforts in at least seven ways: (1) helping visualize patterns of disease and disparity, (2) help identify risk factors, (3) fostering local collaboration and data-sharing, (4) interpreting geographically specific intervention outcomes, (5) identifying the medically underserved populations, (6) planning of interventions for maximum reach and effectiveness, and (7) selecting the most appropriate setting for prevention efforts [7]-[11].

Public health kiosks can potentially be utilized to enhance self-management of chronic diseases, reduce health disparities, better outreach of healthcare services, and can be

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a cost effective way to improve delivery of healthcare services. However, several variables such as digital divide, health literacy, lack of culturally adaptive health information, and limited availability of tailored health material are some of the existing barriers to greater adoption of health technologies and their impact in the improvement of health outcomes. To our best knowledge, there has not been a systematic review to analyze relationships among location, user characteristics, study outcomes, and user perceptions to the technology. Heath kiosks disseminate education and help build skills for better health that reach the medically underserved communities, and approach challenges faced in the field of public health.

The objective of our study is to examine the current utilization of health kiosks in various diverse settings. Further, the study aims to describe the various characteristics of the individuals using these health kiosks. This paper contains five sections. You have just read the Introduction in Section I. Section II describes the methods, and comprised of keyword search, inclusion criteria, exclusion criteria, variable extraction, and statistical analysis. The results of the study are described in section III with the kiosk locations and user characteristics, technology outcomes, components/functions/features of the kiosks, and correlations of user characteristics with technology outcomes. Section IV concludes our paper, and followed by section V explaining future research.

II. Methods

A. Keyword Search

A search was conducted on Medline via Pubmed electronic database [12] to identify the up to date literature about the use of the kiosk in public health settings. The search period was during January 14-January 20 2012 with keywords searched included "public health kiosk", "public health kiosk rural", and "public health kiosk urban" and included articles published during the period of January 2005 to January 2012. A manual review of the literature provided by the electronic database search was conducted to identify relevant articles to include in our analysis. A secondary search was also performed to include the articles that met the inclusion criteria.

B. Inclusion criteria

Those studies that had studied health kiosks in both clinical and non-clinical settings, were in English, and were conducted both within and outside United States were included in our final analysis.

C. Exclusion Criteria

Electronic search entries were excluded if they were not full text peer-reviewed papers, such as abstract submissions or news report articles. Other studies that were excluded included those that focused on the use of kiosks educating individuals on topics not related to health, home based health kiosks, and kiosks that vend/distribute products. Computerized kiosks that were used solely to answer a survey or to collect data for patient check in at a private practice were also excluded.

D. Variable Extraction

The following variable information was extracted from the final analyzable articles:

- Targeted audience: It was aimed to gather information about the different age groups race/ethnicity and gender for which previous studies have been conducted. This will help us in developing better understanding about the usage and acceptance of health kiosks for various socio-demographics.
- Study location: The aim here was to develop a better understanding about the research that currently exists about the implementation and adoption of health kiosks in various developing and developed countries.
- Study setting: This information will help us identify the disparities in the implementation of health kiosks in rural and urban settings. Additionally, "setting location" defines location specificity of kiosks within communities, businesses, and events.

E. Statistical Analysis

Descriptive analysis was performed to report means and standard deviations for the continuous variables and frequency analysis for the categorical variables. All analysis was performed using SPSS version 20 [13].

III. Results

A. Kiosk Location and User Characteristics

The majority of the studies were performed only on adults (56%; n=18), followed by children and adults (38%; n=12), adolescents (3%; n=1), and only children (3%; n=1). The majority of the studies were focused both on males and females (84%; n=27) while only limited number of studies included only females (16%; n=5). Additional variables that might be important to determine use of the health kiosk among various users may include educational status, income, and prior familiarity with use of computers. However, there were few studies that reported this information in the studies included in our final analysis.

Among health care settings, half of the studies placed kiosks in medical clinics (50%; n=16), followed by 28% (n=9) at emergency departments, and 19% (n=6) at community health centers. The other locations utilized by studies were social service agencies (16%; n=5), public libraries (13%; n=4), churches (13%; n=4), health fairs (9%; n=3), beauty salons (9%; n=3), Laundromats (9%; n=3), pharmacies (6%; n=2), and restaurants (6%; n=2). Only one out of 32 studies placed kiosks at a senor apartment (3%; n=1), community center (3%; n=1), grocery store (3%; n=1), Department Motor Vehicles office (3%; n=1), and school (3%; n=1). Of all the 32 studies analyzed, only 5

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TABLE I. NUMBER OF STUDIES DETERMINING THE LOCATION HAVING THE HIGHEST REACH TO PEOPLE ON MEDICARE, MEDIAID, AND NOT INSURED

Order of Kiosk Location Preference	Type of Medical Coverage		
	Medicaid	Medicare	Those with No Insurance
1	Neighborhood Health Center	Church	Public Library
2	Social Service Agency	Public Library	Neighborhood Health Center
3	Medical Center	Laundromat and Beauty Salon	Laundromats
4	Laundromats	Neighborhood Health Center	Social Service Agencies
5	Public Library and Emergency Department	Social Service Agency	Beauty Salon
6	Beauty Salon	Health Fair	Church
7	Church		Health Fair
8	Health Fair		

studies reported the most preferred locations where the health kiosks can be placed. Majority of the studies (60%; n=3/5) reported neighborhood health centers as the most preferred location for the health kiosk. This was followed by public library and social service agencies.

An additional analysis was conducted to determine the preferred kiosk location to reach patients receiving Medicaid, Medicare, and people with no insurance. Of all the 32 studies analyzed, only 4 studies reported the reach of Medicaid users at each location where the health kiosks can be placed. The majority of the studies reported neighborhood health centers (75%; n=3/4) as the most accessed by users on Medicaid. Other highly accessed locations were social service agencies, medical centers, and Laundromats. Only three studies (9%) reported the reach of Medicare users that accessed the kiosk at each location. All three of the studies reported churches (100%; n=3/3) as the most preferred by users on Medicare, followed by public libraries, Laundromats, and beauty salons. One limitation to the preferred Medicare locations is that beauty salons were third, sixth, and seventh order in the three different studies. More analysis is needed to determine the preference of beauty salons among Medicare patients. Only three studies (9%) reported the reach of users with no insurance that accessed the kiosk at each location. The location with the most access among users with no insurance was public libraries (66%; n=2/3). Other highly access locations were neighborhood health centers and Laundromats (Table 1).

Three studies (9%; n=3/32) reported the mean age across different kiosk locations, and consistently show that older populations access health kiosks at churches and health fairs with a mean range of 47.8 to 42.9 years of age. Younger populations access kiosks at beauty salon, social service agencies, library, Laundromats, and neighborhood health centers with a mean range of 33.1 to 36 years of age. Although, the mean age can be shifted from the kiosk health topic presented, the results were consistent across the three studies using the same kiosk at each location.

B. *Technology Outcomes*

The ease of use of the technology (34%; n=11) evaluated the ability of users to operate the kiosk without issues. The kiosk usage (28%; n=9) was evaluated in respect to the users' utilization of the kiosk and its features accessed during use. The usability (19%; n=6) was studied to define the users' ability to navigate and operate the technology, and the presentation of materials by the technology with clear, concise actions provided to the user. Two studies assessed logistical issues (6%; n=2), such as kiosk generated data, and concerns of kiosk. The acceptance (9%; n=3) was evaluated with consumers' approval of the new technology. One study (3%) evaluated the use of the kiosk placed across different locations to differentiate the reach of the kiosk per location (Table 2).

C. *Components/Functions/Features of the Kiosk*

The majority of studies used a touch screen computerized kiosk (78%; n=25), and about half of the kiosks provided printed information (53%; n=17). Four (13%) kiosk systems were able to store personalized health records. Tailored information personalized to the user characteristics was delivered by 75% (n=24) of the studies. Only two studies provided information about the local resources available. Only 5 (16%) studies had kiosks that were Internet enabled, one had (3%) fax capabilities, and six (19%) had a designated personal attendant to guide users. There were limited studies that had reported the use of telephone handsets (9%; n=3), video camera (3%; n=1), microphone (3%; n=1), headphones (3%; n=1) with the health kiosks.

TABLE II. NUMBER OF STUDIES THAT DETERMINE EASE OF USE, TECHNOLOGY ACCEPTANCE, AND SATISFACTION OF HEALTH KIOSKS

Variable Assessed	N	Outcome results	
		Positive Impact	Negative Impact
Usability	6	5	1
Ease of use	11	10	1
Technology satisfaction	6	6	
Technology acceptance	3	2	1
Kiosk usage	9	6	

D. *Correlations of User Characteristics with Technology Outcomes*

Outcomes were analyzed to determine groups with specific characteristics that are significantly correlated with the outcome. The acceptance of the kiosk was analyzed in three studies (9%) and satisfaction in six studies (19%), among studies both were found to be significantly higher among black Hispanics, people born outside of the United States, and individuals with no formal education past high school. Among studies that analyzed usage (28%; n=9), two studies (6%) identified significant results of low literacy users, no formal education past high school, and low-income families of 5000 US dollars or less having the highest usage of the kiosk. The ease of use of the technology (34%; n=11/32), and usability (19%; n=6/32) were readily reported among studies. High literacy, no formal education past high school, and users of the age 36 years or less was positively correlated with ease of use regarding the technology. Usability of the kiosk was correlated with high literacy users, and spending more time at kiosk (Table 3). Additionally, two studies (6%) identified health kiosks were easy to use and accepted among children; with more time spend at the kiosk among younger children.

IV. CONCLUSION

Computerized kiosk systems could be the key to improving public health around the world among diverse populations. Through our review, we identified high usage among low literacy users, no formal education past high school, and low-income families of 5000 US dollars or less. There was high acceptance and satisfaction among black Hispanics, people born outside of the United States, and users with no formal education past high school. Although theoretical framework was not often provided to determine the correlations of specific framework, we can in fact conclude that the technology has the capability of reaching health disparity groups and potentially narrow disparity gaps through the analysis of the perception of the users.

Furthermore, our findings suggest that there are geographic patterns of user accessibility of kiosk locations. Older populations access kiosks at churches and health fairs. The location with the most access among users with no insurance was public libraries, followed by neighborhood health centers and Laundromats. Unanimously, churches were identified the most accessed by users on Medicare. The majority of the studies reported neighborhood health centers and social service agencies as the most accessed by users on Medicaid. Better understanding the patterns would help target appropriate interventions, and in return be more cost effective.

TABLE III. NUMBER OF STUDIES CORREATING USER CHARACTERISTIC AND TECHOLOGY OUTCOME

User Characteristics	Variables Assessed				
	Acceptance	Ease of Use	Usage	Satisfaction	Usability
Low literacy			2		
High literacy		1			1
Black Hispanics	1			1	
Born outside of the US	1			1	
No formal education past high school	1	1	1	1	
Age of 36 years or less		1			
Low income			1		

This review indicates a sustainable and accessible health kiosk would have a positive impact on the prevention and management of a variety of health topics, as well as chronic diseases in communities. The evidence of positive study outcomes across a wide spread of processes suggests a positive impact on communities' health, although there is a need for further research to determine long-term impacts on populations. There can be a sense of community empowerment by providing a resource enabling communities to take their health into their own hands. Studies have shown high rates of kiosk usage among people who are uninsured or underinsured interested in preventative health. Men who are over weight and self-reported being depressed were most interested in kiosk information on weight control. Women who smoke and self-reported being depressed was most interested in kiosk information about smoking cessation [1]. This suggests that individuals are seeking out help, and access education modules provided by the kiosk that are most relevant to improving their own health. Engaging a community in their public's health and providing them with the resources to make a difference, could empower the community to have healthier habits as a social group. An economic analysis, indeed suggests that the role of health kiosks will impact persons who may not otherwise be reached, along with low-income populations and a resource that will becomes extremely cost effective over time [14].

There are several limitations of our study. First, the search included only those studies that were indexed in Pub med. Therefore, we may have excluded studies that might not have been part of it. Second, the search was limited to certain combination of key words that might have resulted in missing of the other reference articles that might have been applicable to our study. However, every effort was made to include additional articles after reviewing and including the references of the primary articles in the final analysis after they met the inclusion criteria.

V. Future Work

There is a need to compare and contrast the use of the health kiosks among different countries, as several factors might impact the overall health kiosk usage in these countries. These factors might include social, political, cultural, organizational and logistical variations, and challenges among populations and other stakeholders. Further research is needed to examine health kiosk usage patterns stratified by age, gender, occupation, income, educational status, and prior computer skills of the individuals.

An understanding of usage patterns can help us better assess the impact of health kiosks in improving overall health outcomes among diverse user groups. Additionally, there is the need for more comparative studies among kiosk locations within communities to identify optimal settings for kiosk placement, and among a wider variety of settings.

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Multi-functional Wireless Body Sensor

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***Abstract*—A wireless multi-functional body sensor for monitoring vital bio-signals is proposed. The sensor uses modern, moderately priced, user-friendly and robust technology solutions. It supports advanced algorithms for local analysis of data and communication infrastructure to widely available personal terminals for visualization of measurements, and further transfer of critical data, either to medical experts or to a personal database. We pay a special attention to the fusion of different sensing functions in a single multi-functional sensor. To improve the reliability and robustness of the system, the measured signals, e.g., ECG, light, voice, acceleration, etc., can be combined in order to prevent the rising of false alarms. The proposed multi-functional body sensor contributes in significantly elevated quality, unobtrusiveness and robustness of the health care and patient safety.**

Keywords - multi-functional body sensor; wireless; mobile; healthcare; monitoring

I. Introduction

The introduction of modern information and communication technologies (ICT), as support to medical activities, is one of the possibilities to increase the efficacy of the health care system and to decrease its costs. This basic premise is included in all strategic plans of the EU and the rest of the world. Numerous studies have confirmed the benefit of the development of Telemedicine/Telecare systems [1, 2]. We are proposing a multi-functional wireless body sensor (MWBS) that uses modern, moderately priced and user-friendly technology solutions. It is appropriate as a building block in systems for continuous monitoring of hospitalized patients, post-hospital care, or diagnostic long-term monitoring. It measures vital functions, e.g., heart beat rate, blood pressure, body temperature, etc. Classically, these measurements are performed by nurses several times a day and then manually entered in the patient's charts. In addition to the issue of intermittent monitoring of vital functions in non-intensive wards, there are other weaknesses in the current health care system. The interpretation of the patient's condition and the consequent measures taken depend on the personnel, who could be, in certain conditions, overwhelmed with work or busy with other patients. The measured indicators can also be inaccurate - sometimes being biased by the presence or the inexperience of the medical personnel and therefore unreliable.

In proposed systems for remote monitoring of vital functions [3, 4], patients or monitored subjects are fitted with several body sensors for vital functions, which communicate with personal terminals (size of a mobile phone) via wireless connections. The measurements are stored in the personal terminal for monitoring and processing with automated procedures based on comparison with threshold values, predetermined rules and automatic learning. The data are sent, either periodically or because of unusual events, to a computer server that maintains a database and is responsible for presentation, alerts and necessary actions.

Taking into account that unobtrusiveness and robustness might be decisive factors for the success of the future bio-monitoring systems, we concentrate on these two issues. We investigate options for the development of the MWBS and integrations in final monitoring systems that can fulfill both requirements.

The rest of the paper is organized as follows. First, the architecture of the proposed system for remote monitoring of vital functions is presented. Next, the implementation of the system is described, elaborating the role of the wireless multi-functional body sensor, the concept for improved alarms using environmental sensors, and the platforms for transmission, representation and collection of data from the sensors. The paper concludes with a summary of our findings and potential future extensions of the proposed multi-purpose body-sensor approach.

II. System Architecture

The architecture of the proposed system for remote monitoring of vital functions is shown in Fig. 1. The design of the system takes into account the existing technical standards, allowing easy connection of various body sensors and their immediate replacement, if an improved version becomes available. The system allows connection of new sensors, which could help in the improvement of the monitoring of the patient's condition, for example, sensors for remote monitoring of respiratory acoustic phenomena (cough, obstruction), simple video sensors, etc. Some of the measurements are feasible with our custom sensors [5]; for others, like blood pressure measurements, new unobtrusive and non-invasive body sensors are to be developed.

The transmission of the measurements to remote places is done by existing infrastructure (Ethernet, Bluetooth, Wi-Fi, etc.) and the Internet, which offers an inexpensive implementation, as well as wide availability. The information is available on site and controlled/monitored by

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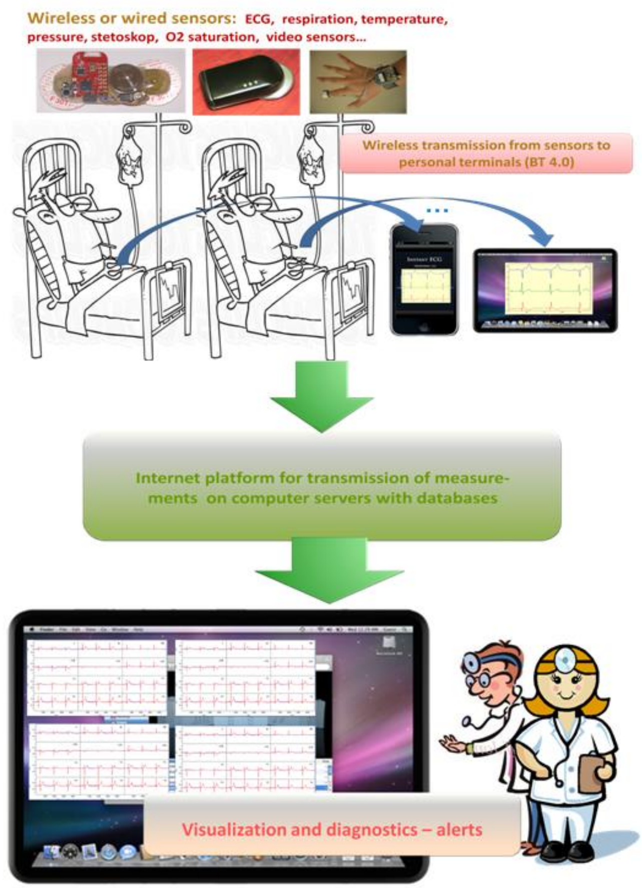

Figure 1. Architecture of the system for remote monitoring of vital functions. All sensors should be merged into a single multi-functional unit.

the staff on call, which enables immediate detection of deterioration in the patient's state and prompt actions.

Based on the simultaneous evaluation of multiple variables, the system will provide the threat level and its trend [6]. The analysis of vital functions in a longer time period allows for the implementation of cognitive methods; for example, analysis of a cardiogram over longer time period contributes to personalized patient's threat level [7, 8].

III. Implementation Concepts

The implementation of the proposed system significantly increases the research potential of medical institutions. The system provides documented measurements and events obtained in an objective manner during different stages of the well being of patients or other users (elderly, athletes, etc.). The system could be upgraded with new medical research methods. Following are related research activities and findings that contribute in the system implementation.

A. Development of multi-functional body sensors

Body sensors should be non-disruptive to users; therefore, we consider small and multi-functional wireless sensors. We have already prototyped a differential wireless bio-electrode (WBE) for measuring ECG [5] and EEG. Within the WBE, other sensors can be incorporated towards the final version of the MWBS. We have currently identified the following options:

bio-sensors

- heart beat rate,
- blood pressure,
- respiration,
- temperature,
- oxygen saturation,

environmental sensors

- acceleration,
- position,
- audio recording,
- video detection.

The wireless technology considered for transmission of measured data from the sensors to personal terminals is the newest version of Bluetooth technology – low energy Bluetooth 4.0 (BT4). It enables direct communication between the MWBS and newest Smart phones and devices with incorporated Bluetooth Smart technology.

Bluetooth low energy protocol is low-cost wireless solution designed to meet special requirements for long-term operation in devices with limited energy capacity (e.g. coin-cell battery). Its ultra-low peak, average and idle mode power consumption and enhanced working range enables the MWBS to operate on a single coin-cell battery for several days while transmitting live stream of raw ECG data. Based on our preliminary measurements, we conclude that the BT4 enables 4 days of external power supply independency for a MWBS with a small coin battery. The maximal bit-rate of the data payload is 1 Mb/s, which is sufficient also for high-resolution short-term measurements.

Other features can be also added to the MWBS: vascular pressure, oxygen saturation, skin resistance and respiratory rate measurements. Furthermore, microphones, accelerometers and video sensors could offer additional environmental data that contribute to a better estimate of the status of the monitored patient. An example of the prototype multisensory electrode is shown in Fig. 2a. It is equipped with a BT4 radio and sensors for ECG, respiration acceleration and light. On the measured raw ECG signal (Fig. 2b), a respiration signal as an envelope of the R-peaks is clearly visible.

The ECG-Derived Respiration (EDR) techniques relevant to our work are based on the observation that the positions of the ECG electrodes on the chest surface move relative to the heart. We confirm, with the analysis of clinical multichannel ECG measurements, which include also reference thermistor based respiration signals, that the proposed approach is a viable option for the monitoring of the respiration frequency and for the rough classification of the breathing types [9]. The obtained results are evaluated on a wireless prototype of respiration body sensor from Fig. 2. We indicate the best positions for the respiration body sensor and prove that a single sensor of body surface potentials

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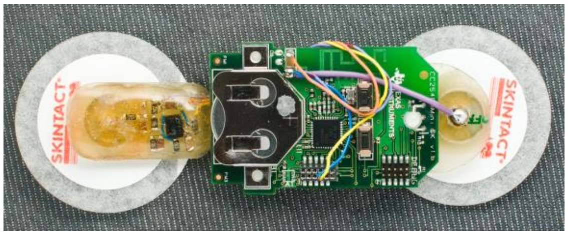
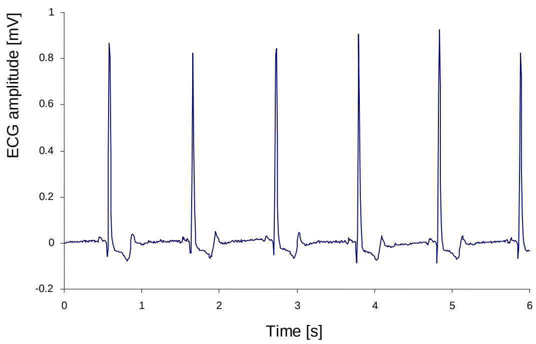
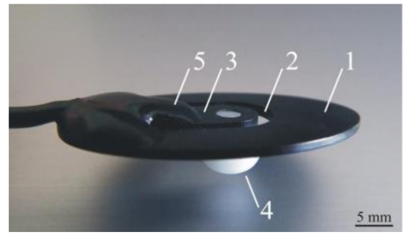


(a)

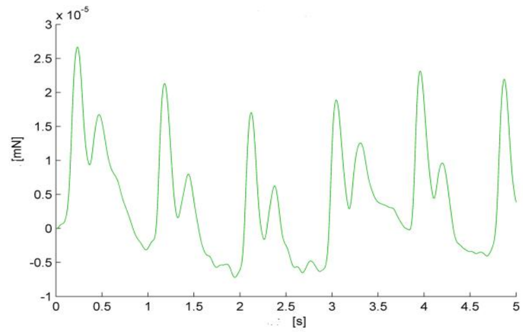


(b)

Figure 2. (a) A prototype of the MWBS with two self-adhesive disposable electrodes, a lithium coin battery, micro-processor, BT4 radio, and printed circuit board antenna. (b) An example of an ECG recorded wirelessly – raw signal.



(a)



(b)

Figure 3. (a) A prototype of the muscle contraction (MC) sensor: (1) laminate, (2) incision, (3) tonguelet, (4) sensor tip, (5) strain gauge. (b) An example of measured tactile pulse.

difference on proximal skin electrodes can be used for combined measurements of respiratory and cardiac activities.

A new prototyped muscle contraction (MC) sensor [10] is considered for integration into the system. The sensor is relatively small and light. It is based on a novel principle for measuring muscle tension during muscle contractions and provides important data about patient's muscular activities. Additionally, we consider the option to use the MC sensor for detection of the tactile pulse. The sensor could be also adopted for measurement of changes in the blood pressure. An example of the prototype MC sensor and a preliminary measurement of the tactile pulse are shown in Fig. 3a and Fig. 3b, respectively.

In clinical medicine, the gold standard for diagnosis of pneumonia is the X-ray imaging; nevertheless, in a clinical examination, pneumonia is diagnosed only in a small proportion of ill children. Computer analysis of the sounds in adult patients with pneumonia has been proved to confirm the diagnosis [11]; however, the method uses sixteen microphones, which is not suitable for clinical use. The proposed system enables development of convenient and computerized systems, designed by a smaller number of microphones, which spare the patients from the X-ray radiation.

One of the advantages of the proposed system is the ability for continuous monitoring of ECG. In a recently published study on children with RSV bronchitis, the presence of abnormal heart rhythm was also found [8]. Long-term monitoring of ECG is an important source of data for confirming the correlation of the two diseases, which is not known so far. We can aggregate different sensor data and, using rule-based algorithms, devise higher-level diagnostic conclusions on medical or rehabilitation status of users.

In some rare cases, more body sensors are still needed. An example is the synthesized 12-lead electrocardiogram (ECG) [12], which is the gold standard in cardiology.

B. Improved alarms with environmental sensors

One of the most critical problems that influence a sustainable use of monitoring systems is issuing false alarms. The personnel that assists and manages a monitoring system cannot tolerate false alarms above some minimal limit. We pay special attention to overcome this problem with multilevel alarms based on data from more than a single sensor. To improve the quality of patients' status interpretation, we introduce visual sensors consisting of simple and low cost video detectors [13]. Visual sensors will not allow interference with personal intimacy. The video detectors cover just a near area of the patient's bed and, after a simple local video processing, detect and store patients' motion, movement and position. Based on these additional data, an improved reliability of raised alarms can be obtained.

C. Platforms for transmission, representation and collection of data

The transmission of data from the sensors, and later its representation, are planned on two levels: to the patient itself and to the medical personal.

First, we have wireless transmission of the measured data from the sensors to personal terminals, like Smartphones or other portable smart devices. Custom made applications provide the opportunity for suitable representation of the transmitted data and the possibility for the patient to monitor its vital functions. We have already developed an application that provides a comfortable option for telemonitoring of the heart activity. We use the prototyped wireless bipolar body electrode to record ECG wirelessly, coupled with the advantages of existing portable smart devices to display the real-time data from the electrode [14]. Local processing of the measured data and alarm triggering can be done already on the sensor or on the portable device. For example, the respiration rate can be calculated on the sensor, while the reconstruction of the standard 12-lead ECG can be performed on the Smartphone for the visualization of the reconstructed signal.

Second, a SOAP (Simple Object Access Protocol) client on the portable platform transfers relevant data (for example, ECG data when an alarm has been triggered) to a computer server. The transferred data on the server [15] is appropriately visualized to the medical personal for diagnostic purposes, and also is collected in a database for further analysis.

IV. Conclusion

We have designed a system for continuous remote monitoring of patients at risk, which is based on multi-functional wireless body sensors. We thus contribute to significantly elevated quality, unobtrusiveness and robustness of the health care and patient safety. Widespread, accessible, and tested ICT solutions from the field of measuring sensor systems, mobile communications and network services, are incorporated into the system. Medical expertise are also included through the software for analysis of multi measurements, as well as the triggering of alerts and alarms for urgent action. The responses of medical personnel to clinical deterioration in patients will be faster; therefore, the patients will experience fewer complications in case of sudden deterioration of their health. The work of medical personnel will be less stressful and more efficient.

The applicability of the proposed system is not limited only to hospitals and health care centers, where the added benefit of the system will enable "doctor-to-doctor" and "patient-to-doctor" communication. The system can be also installed in nursing and patients' homes, e.g. for early postoperative care. The patient-friendly approach will contribute to easier diagnostics and reduction of healthcare costs.

We developed and evaluated a prototype of multi-functional sensor that can record main features of ECG, respiration, and acceleration. Further sensing options, e.g., temperature and MC, are under development and laboratory testing. It is clear that the proposed approach is ideal for users from the comfort point-of-view; however, the main focus of our future work is in the evaluation study of long-term functional performances, including data security and privacy, and added diagnostic value of the proposed system.

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Security Factors for Healthcare Data

Comparing the Security Threats of Online Banking and Healthcare Information Systems

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***Abstract*—The number of information security threats in healthcare information systems is increasing tremendously. There are various factors that contribute to these information security threats; most researchers are mainly focused on certain factors such as virus attacks and malware. Thus, certain important factors may have still remained unexplored. In addition, the lack of tools and technologies can also contribute to the limited number of threats recorded in the healthcare system. In this paper, we summarize the security threats in online banking and healthcare information systems (HIS) and analyze the relationship of risk factors through comparison. The findings will serve as recommendations for healthcare service organizations to fill the technology gap between the online banking and HIS security systems.**

Keywords - Online banking security; Healthcare security; Information security; HIS; Security threats.

I. INTRODUCTION AND MOTIVATION

Nowadays, computer and network-based systems are expanding in order to support more healthcare activities, especially in isolated regions (i.e., isolated rural areas in Greece, Scandinavia and Germany), where there is often no availability of central general hospitals. Networked healthcare information systems can fill this gap, by connecting local healthcare service providers with central regional or peripheral hospitals to make tele-consultation, tele-diagnosis and exchange of views possible between remote located doctors in certain patient treatment cases.

Furthermore, medical data maintained in a health information system is directly related to the patients' health and safety. According to the recommendation on the protection of medical data issued by the Council of Europe [1], appropriate technical and organizational measures must be taken to protect personal data against any accidental or illegal destruction, accidental loss, as well as against unauthorized access. These possible threats can severely damage a health information system's reliability and discourage professional use in the future. Therefore, the execution of a risk analysis is a necessity in order to assure a health information system's safety and Quality of Service (QoS) [2].

This study intends to analyze the security threats of health data. First, a review of the information security threats are included and discussed. Beside this, we also compare the existing security threats of online banking with the healthcare information system (HIS). In both cases, the security factors include hacking and blocking as well as accidental and deliberate cases, and also the possibility to change a sensor from one patient to another.

Personal medical information is in various aspects similar to financial data. Accidents caused by incorrect medical information can lead to large-scale litigation, and also translate directly damage to a person's life. According to the estimation of the IOM (Institute of Medicine) under the U.S. Department of Health and Human Services, as many as 98,000 patients per year are estimated to die due to wrong medical information [3]. This occupies eighth place in the United States on the list of the 10 leading causes of death; it is higher than the mortality due to traffic accidents, breast cancers and AIDS.

As for financial institutions, in 2007, one million people in Japan lost their pension paid records. Due to government mismanagement, the data quality may be lost, which may lead to pay back in 25 years according to pension specifications.

Through these incidents, we can see how huge the impact is to the society, both in case of healthcare and financial data, when an incident is about money loss or threat to human life. Currently, there is a clear need for efficient security models in banks or medical institutions, which offer their customers access into their system via Internet.

Online banking started with Security First Network Bank (SFNB) in 1995 [4], and is now rapidly increasing with hundreds of millions of users' across the globe. Many researchers have studied various security threats and its solutions for online banking. On the other hand, the security of personal health information is still not well in order. For this reason, even though it cannot prevent all kinds of security threats, the online banking system has a better security model.

Since healthcare data is at least as important as financial data, the purpose of this paper is to comprehend the factors, which are important in healthcare through this study. We attempt to classify the security threats on each side and analyze the security threats of healthcare information through a comparison with the existing threats of online banking. Also, we describe some online banking security models that can be applied to HIS.

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The next section describes the previous studies related to this research. Section III presents the comparison of online banking security and healthcare information system, and Section IV describes some Internet banking security models that can be applied to HIS.

II. RELATED WORKS

In this section, we describe the information security threats as well as summarize the existing security threats in online banking [5] and healthcare information systems [6].

A. Threats to information security

Information security threats can be classified into three categories, as found below [7][8].

First, there are environmental threats, which include natural disasters and other environmental conditions. Earthquakes, fire, floods and storms are examples of natural disasters. The likelihood of a natural disaster affecting an organization is greatly dependent on its location, information processing facilities and stored data. For example, a computer facility near bush land will be more likely to be affected by bushfire than one that is located in the city area. The failure of a power supply is an example of an environmental conditions threat, when uninterruptible power supply equipment and back-up file systems are not available.

Secondly, deliberate threats are those threats that involve the destruction or manipulation of data, software or hardware. These threats include denial of service, malicious code such as viruses and worms, theft and fraud. Various vulnerabilities are identified to be the cause of these threats such as inadequate network management (resilience of routing), lack of firewall, not using the latest version of the operating system and lack of physical security.

Lastly, accidental threats are threats that are related to errors and omissions. Errors and omissions by employees or insiders are the main causes of information security problems [9].

A communication failure could be caused by accidental damage to network cabling, loss of network equipment such as routers or servers and software failure. Examples of vulnerability, which could lead to an incident, include lack of redundancy and back-ups, inadequate network management, lack of planning and implementation of communications cabling or inadequate incident handling. Due to the existence of so many variables that can possibly occur as threats to a computer system, it is useful to have an appropriate tool for threat analysis [10].

Since there are many variables that have no possibility to become threats to a computer system, it is very important to come out with an appropriate tool to perform threat analysis. Using an appropriate tool will enable the system to analyze threats accurately and come up with the best solution on how to overcome these security threats.

B. Online banking security threats

Due to its benefits, which allows internet users to access and manage their bank accounts from anywhere on the world at any time, online banking has now grown rapidly from a niche service to a major new way of banking. However, since the Internet is not originally designed for online banking, online banking is now facing a wide range of security risks for both the banks and the online banking users such as brute-force attacks, distributed attacks and social phishing. Therefore, the banks have to improve their online banking security systems constantly, which means the banks have to keep investing in security systems all the time.

Online banking is a series of processes in which a bank client logs onto the website of the bank through a web-browser installed on the PC and carries out various transactions such as account transfers. Online banking is carried out in four major stages, illustrated below in Figure 1.

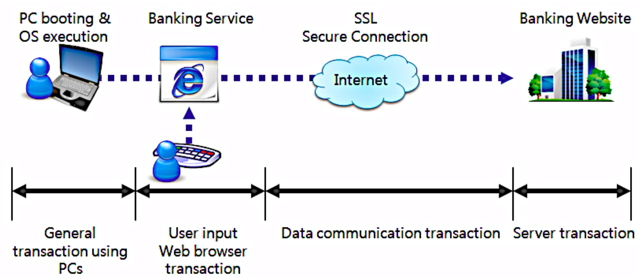

Figure 1. Online Banking Transaction [5].

a. The user turns on the PC and boots the OS.
b. After the web-browser is open, the end user accesses the online banking website of the bank and enters the ID or Personal Identifying Number (PIN) and the password by using the keyboard.
c. The data input is encrypted by SSL (Secure Socket Layer) and transmitted to the bank's server.
d. The bank's server decrypts the transmitted information and processes the user's authentication, account inquiry, account transfer, etc.

The ordinary PC environment is exposed to many types of threats because of insecure web surfing and use of a variety of unverified programs. If a user carries out an online banking transaction in an environment that is exposed to such kinds of threats, there is no way to guarantee the safety of that online banking transaction.

Most of the recent hacking tools are circulated throughout the web and they can be inadvertently downloaded and executed in the user's PC while the user is enjoying of web surfing or checking e-mail.

Once these hacking tools are planted into a user's computer, they will then capture the password, account number and personal data, which the user is typing. Furthermore, they are even capable of replacing the input screen that the user is watching with a counterfeit website of the bank, which the hacker had installed in advance. The user's input data are not transmitted to the bank because these hacking tools redirect the user's input data to the hacker's server instead for illegal account transfers. Thus hackers and hacking tools can attack the system using many tricks in a number of different ways during the online banking process, as shown in Figure 2.

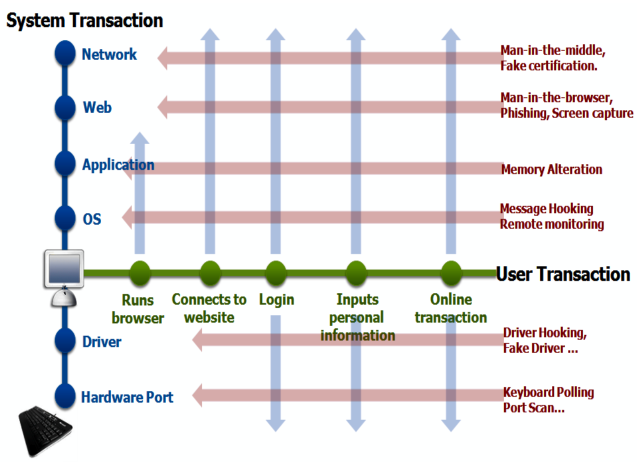

Figure 2. Threat can pervade every stage of the transaction [5].

C. *Healthcare information system security threats*

Today, the usage of information systems in the healthcare environment provides many potential benefits such as improving the quality of care, reducing medical errors and enhancing the readability, availability and accessibility of information. However, HIS security threats have increased significantly in recent years as well. Therefore, storing health information in electronic form has raised concerns about a patient's health, privacy and safety. Basically, HIS is threatened by both accidental events and deliberate actions, which can severely damage the reliability of HIS and consequently discourage professionals to use it.

Furthermore, the lack of adequate protection for sustaining confidentiality, integrity and availability aspects leads to the need to investigate potential threats, particularly in the HIS domain. In addition, weakly organized security management and unawareness of risk analysis practices, especially in the healthcare organizations, need particular attention.

The International Standard for Health Informatics for Information Security Management in Health, using ISO/IEC 27002 (ISO27799: 2008) [11], has defined HIS as a repository of information regarding the health of a subject of care in computer-processable form, stored and transmitted securely and accessible by multiple authorized users. There are various types of threat categories introduced in this standard. It classifies HIS threats into 25 types.

Basically, the HIS threats have been classified into two main categories, namely, internal threats and external threats [12]. The internal threats include various types of employees' behavior such as an employee's ignorance, curiosity, recklessness, inadequate behavior, taking someone else's password and giving a password to another employee. The external threats include viruses and spyware attacks, hackers and intruders on the premises.

In addition, HIS threats can be categorized into 19 types based on case studies conducted using the selected risk analysis method [2]. One finding shows that the most critical threat to the HIS is a server power failure. Furthermore, a power failure in a workstation, a network software failure and a tele-monitoring software failure also present high-risk threats. Besides this, there are also a number of high-risk threats related to human factors, such as user errors in using the HIS and the masquerading of the user's identity during system operation.

Furthermore, another study has identified 25 types of patient monitoring system threats [13]. The most critical threat is a power failure of the server, while the power failure of a personal home computer is the second most critical failure for the system. Also, air-conditioning failures, system and network software failures, monitor support software failures and medical record software failures are also treated as the high-risk threats. However, this study also identified a number of high-risk threats related to human factors, such as user errors in using masquerading software.

III. COMPARISON OF INTERNET BANKING AND HEALTHCARE INFORMATION SYSTEM

In this section, we provide a classification of security threats based on existing research results and comparison between online banking and healthcare information systems based on important security comparison factors.

A. *Classification of threats*

Figure 3 presents the known threats, which affect each security method discussed in this paper.

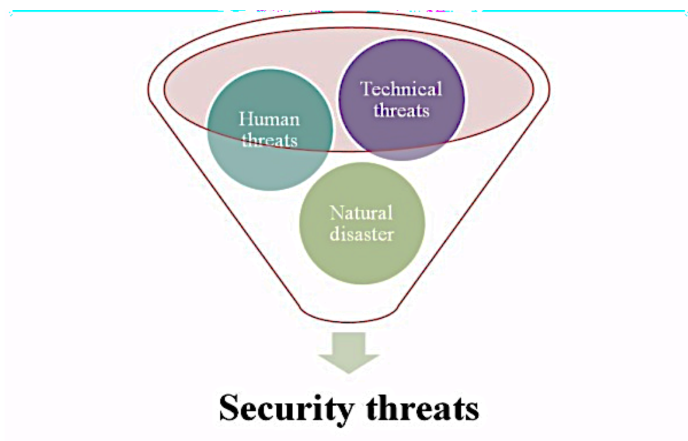

Figure 3. Classification of threats.

It does not present all the threats, which may exist in such a method, but it shows that those methods are currently vulnerable to several attacks. Basically, the threats were categorized based on relevant standards [11][14] and also based on a comparative study of previous works and publications in this research.

We have classified the threats into three categories, which include technical threats, human threats and natural disasters. First, technical threats are caused by a technical problem, such as the technical failure of a network or system, a variety of malicious attacks through malicious code, etc. Human threats belong to information leakage by insiders or staff, and unauthorized user access, user's negligence, etc. Finally, there are threats of natural disasters, caused by a

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variety of adverse circumstances, such as water damage, fire and earthquake, etc.

In Figure 4, the technical and human threats are classified in more details.

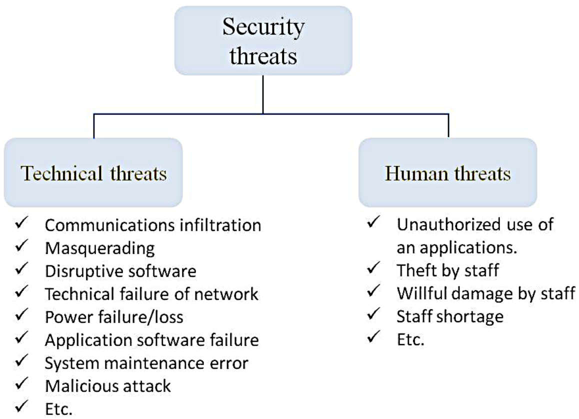

Figure 4. Classification of technical and human threats.

B. *Comparison factors*

Table I depicts 13 types of factors according to the major threat categories. We consider four categories for comparison, such as authenticity, confidentiality, integrity and availability, which are general factors in cryptography.

TABLE I. COMPARISON FACTORS

	Factors	Description
Authenticity	Password	How many digits and what kind of combinations are used?
	Authentication	How to provide authentication?
	Transfer protocol	What kind of protocol to be used for data transfer?
	Unauthorized access	How can the access of an unauthorized user be prevented?
Confidentiality	Communication interception	How can interception by a malicious third party be prevented?
	Data encryption	What kind of algorithm is used for data encryption?
	Non-repudiation	How to achieve non-repudiation?
Integrity	Social engineering attacks	Impersonation, persuasion, bribery, shoulder surfing and dumpster diving, etc.
	Malware attacks	Malicious virus, worm, Trojan horses, spyware and adware, etc.
	Acts of human error or failure	Entry of erroneous data by staff, accidental deletion or modification of data by staff
Availability	Power failure	Server down due to power failure, Air-conditioning failure of the server, Interruption by service provider
	Hardware/software failures or errors	Insufficient storage software, Hardware/Software maintenance error, Application software failure
	Natural disaster	How can the failures from fire, water-damage etc. be prevented?

At first glance, it might seem that authenticity is included in the concept of integrity. Integrity is more specifically about the content of the data itself. Authenticity involves the assurance that the data was created or sent by the source it appears to be from.

Integrity, as a concept, means that there is resistance to alteration or substitution of data, and/or that such changes are detected and traceable. When data might be changed by accident or malice, preventing the change is of the first concern, and detecting it is the second. Integrity can be maintained on many levels, from hardware to application logic.

Confidentiality means, at the core of the concept, that the data is hidden from those are not supposed to see it. We can accomplish confidentiality in a number of ways such as ensuring encryption of the data so that it cannot be intercepted or accessed during transmission or transport etc. While encrypting is a sure way of keeping the data confidential, it is not the only way.

In any information system, the information must be available when it is needed. This means that, the security controls and the communication channels used to access it must be functioning correctly. High availability systems aim to remain available at all times. It attempts to prevent service disruptions due to power outages, hardware failure, and system upgrades. Ensuring availability also prevents denial-of-service attacks.

C. *Results and analysis*

From Table II, we can see that the result of comparison between online banking and healthcare information systems applies various factors. We have analyzed the requirement per each item for providing sufficient security and also provided information on the currently used technologies. For the analysis we have investigated the most common technologies both in online banking and healthcare information systems.

First, in online banking, a password is employed combining characters and numbers within 30 digits using a virtual keyboard to prevent a key logger. In addition, to authenticate the use of OTP (One-time password) and certificate, it uses the HTTPs, SSL/TLS protocols for secure communications. Some technologies are dependent on a system, such as a firewall, browser protection, backup system, etc. Also, to prevent communication interception, a pass-phrase, firewall, SMS and transaction monitoring are commonly used. The pass-phrase is a security model based on information held by the user. It is usually used as a second authentication method in a transaction that involves money transfers.

Some cases of healthcare information Systems (HIS) are using a six-digit character password, depending on the system. The transport protocols are TCP/IP (Transmission Control Protocol/Internet Protocol) and FTP (File Transfer Protocol) for file transfers and data encryption formed using WEP (Wired Equivalent Privacy) or WPA (Wi-Fi Protected Access), if using wireless communication; it also performs data encryption using PKI (Public Key Infrastructure).

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TABLE II. COMPARISON RESULTS

	Factors	Requirement	Online Banking	HIS
Authenticity	Password	Combination of numbers and characters of more than 8-digits or Bio-metrics	Mixed numbers and characters within 6 to 30-digits, virtual keyboard	6-characters (depending on the system)
	Authentication method	Using high-grade security media	Digital certificates, OTP, security card, etc.	No fixed rules
	Transfer protocol	Mutual and secure authentication protocol	HTTPS, SSL/TLS	TCP/IP, FTP
	Unauthorized access	Strong password techniques One-way hash functions Use of personal characteristics	Firewall, Access control technologies	Firewall, Access control technologies (depending on the system)
Confidentiality	Communication interception	Transaction monitoring secure	Pass-phrase, Firewall, SMS, Transaction monitoring	WEP/WAP
	Data encryption	Cryptographic algorithm (i.e., AES-128, SEED)	128-bit SSL encryption 256-bit SSL encryption (EV SSL)	PKI (Public key infrastructure)
	Non-repudiation	Digital signature	Digital signature through certificates	Digital signature
Integrity	Social engineering attacks	defined consequences for violating the policies, education and training	Positive identification	Positive identification
	Malware attacks	Firewall, anti-virus software, real-time monitoring	Browser protection	Browser protection
	Acts of human error or failure	Regular security audits Limited access to system	Regular security audits Limited access to system	Depending on the company policy
Availability	Power failure	Auxiliary power, Backup system, alarm, etc.	Backup system (depending on the system)	Backup system (depending on the system)
	Hardware/software failure or errors	Regular system maintenance	Regular system update and maintenance	Regular system update and maintenance
	Natural disaster	environment monitoring (i.e., Fire detection sensor)	Real-time environment monitoring in server room	Real-time environment monitoring in server room

On the other hand, to prevent availability breakdowns, through such incidents as power failure, system errors, system failure or natural disaster, both systems provides a backup system, regular system updates and maintenance, etc., but it depends on the system. In the case of integrity maintenance, the use of positive identification, browser protection software or the introduction of some policy such as regular security audits and limited access to system, were implemented. However, those also depend on the system. For reference, positive identification is a model where the user is required to input some secret information only known to him in order to identify himself.

IV. DISCUSSION

In this section, we describe some online banking security models that can be applied to HIS. Many different advanced fraud detection technologies are being applied for fraudulent detection and prevention of online banking transactions. Hence, if a system has better security control, the threats can be reduced.

A basic knowledge of authentication is an important step towards security control. Authentication is any process by which you verify that you are who you claim to be and have been permitted to access to a system. In the online banking case, there are a variety of technologies and methodologies financial institutions can use to authenticate a customer. These methods include the use of customer passwords, personal identification numbers (PINs), digital certificates using a public key infrastructure (PKI), physical devices such as smart cards, one-time passwords (OTPs), USB plug-ins or other types of "tokens", transaction profile scripts, biometric identification, among others. The level of risk protection afforded by each of these techniques varies. Thus, online banking systems are used according to their combinations. The selection and use of authentication technologies and methods should depend upon the results of the financial institutions' risk assessment process. If we can apply these various techniques to HIS, this can be a safeguard against unauthorized access and use.

The following proposals are examples of security models that can be help to provide authentication. Hiltgen et al. [15] presents two challenge-response online banking authentication solutions – one based on short-time passwords and the other on certificates – and then describes how easily these solutions can be extended if sophisticated content-manipulation attacks arose. The short-time password solution use symmetric cryptography in combination with a hardware security module (smart card) and an offline (stand-alone) smart-card reader. This solution provides convenient mobility for people who want to bank online anytime anywhere, not just from their homes.

In the certificate-based solution, a two-stage, PKI-based online banking authentication solution is used. It is characterized by open standards and a programmable, certified, secure, smart-card reader connected to a potentially exposed PC. This solution uses a dedicated FCR (FINREAD card reader) along with an appropriate financial transactional IC card reader (FINREAD) and financial card reader identification application (FCRIA), both of which are loaded onto the user's FCR to secure the authentication process.

Tiwari et al. [16] proposes an authentication system that is both secure and highly usable, based on a multi-factor authentication approach. It uses a novel approach to create an authentication system based on TICs (Transaction Identification Code) and SMS to enforce an extra security level for the traditional login in a username/password context. TICs are user specific unique transaction identification codes, which are issued by banks or financial institutions for their users. This code is similar to the One-time Password (OTP) and the code is used only once. This paper also suggests an encryption/decryption technique that would be used to keep TICs as secret codes on cell phones/PDA. The user can easily pick up a TIC (from the stored list of TICs) to initiate a secure web transaction using her/his cell phone/PDA, instead of typing a complicated TIC code in each transaction.

Dandash et al. [17] presents a security analysis of a proposed online banking model compared with current existing models used in detection and prevention of fraudulent Internet payments. Their proposed model facilitates online banking Fraud Detection and Prevention (FDP) by applying two new secure mechanisms, a Dynamic Key Generation (DKG) and a Group Key (GK). Such mechanisms satisfy all transaction security properties of payment systems as they enforce strong authentication and authorization methods.

Hu et al. [18] proposes a secret key based security scheme for achieving secure online banking. Encryption equipment is adopted at certification servers and client terminals and a secure certification protocol is established by using secret key encryption, combined secret key and smart card techniques. In this paper, the encryption hardware and secret key encryption algorithm passed the security tests performed by an authorized department. Along with this, the use of authentication and digital signature certification guarantee double security. Also, a one-time secret key is generated automatically according to a generation algorithm and is unrepeatable.

In addition to this, a mutual authentication, also called two-way authentication, is a process or technology in which both entries of a communications link authenticate each other. In a network environment, the client authenticates the server and vice-versa. In this way, network users can be assured that they are doing business exclusively with legitimate entities and servers can be certain that the users are attempting to gain access for legitimate purposes. Currently, mutual authentication is gaining acceptance as a tool that can minimize the risk of online fraud in e-commerce. If we can apply this to HIS, it can reduces the risk that an unsuspecting network user will inadvertently reveal security information to a malicious or insecure web site.

Institutions should establish a firm policy to provide availability in case of power failure, hardware/software failure or error and human failure or error. The policy, such as regular security audits, system updates or limited access, could help to reduce security accidents.

V. CONCLUSION

This paper aims to investigate the current debate regarding the threats and vulnerability of healthcare data. It reviews some possible remedial actions to defend against these threats. The aim of this research was to critically analyze existing research and findings dedicated to healthcare security issues and its information security problems.

We found that although the findings of the reviewed research are somewhat contradictory, the Internet is mostly seen as a security threat. Some technologies, such as anti-virus software; spam guard; email filtering and encryption; firewalls and so on, are used successfully by the service provider organizations to protect the information. However, some areas are still vulnerable to security threats.

The awareness of information security is now growing rapidly. In the long run, information security will be one of the most important issues for modern organizations. The inclusion of biometrics, encryption, digital signatures, intrusion detection systems, security education and training, virus control and compliance with data protection legislation and policy will be of primary importance. The findings of this study will serve as recommendations for healthcare service organizations when defining requirements for the security issues. Simply speaking, it is a question of filling the technology gap between the security solutions in the online banking and healthcare information systems.

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"Concept Car" Design Method in Medicine: Redesigning an Incubator's Mattress

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***Abstract* — When a child is born premature, he is usually placed inside an incubator in the hospital's Neonatal Intensive Care Unit. With the goal to design a new mattress for within these incubators a multidisciplinary consortium was established. In order to broaden the creative space, and, thus inspire further innovation, the design team decided to develop a controversial, but plausible incubator bed prototype through a "concept car" approach. This paper describes the process of introducing the "concept car" method into a medical setting and its effect within a multidisciplinary consortium. Through an in depth discussion and presentation of the prototype, an evaluation of the design was achieved. Questions, discussions and criticism were elicited from the consortium partners, which would serve as inspiration material for future developments within the consortium. This way of realizing ideas into a 1:1 scale prototype proved to stimulate inter-disciplinary thinking and opened doors to creativity on various levels.**

Keywords-neonate; incubator; innovation; concept car; multidisciplinary; design.

I. INTRODUCTION

Within this paper, we describe the process and development of an incubator mattress design within a multidisciplinary consortium (MC) composed of neonatologists and nurses, designers, engineers and mattress developers. The method used for the development is called "concept car" design. The goal of using this design method was to broaden the creative space and thus inspire further innovation within the consortium. We describe the development of the mattress design, its effect on the creative mindscape of the MC and why we believe the design is unique in the field of neonatology.

A. Neonatal Intensive Care Unit

If a child is born extremely premature, before the gestational age of 32 weeks, the child is small, fragile and most likely in a life threatening situation. In order to give the child the protection and (medical) care it needs, the child is placed inside an incubator in the hospital's Neonatal Intensive Care Unit (NICU).

Due to the, usually, unexpected child birth, sudden hospitalization of the child and stress over the uncertainty about their child's future, parents tend to experience difficulty in their efforts to bond with their child [1].

Luckily, however, in the past decades, the mortality among IC neonates has been substantially reduced by the introduction of new innovations in the fields of technology and medicine [2]. However, the long-term cognitive, neurological and behavioral developments of the neoanates are still undesirable compared to full term neonates [2].

B. Incubator design history

The first incubator for prematurely born infants was developed in the year 1880 by the French obstetrician Stéphane Tarnier [4]. Inspired by incubators for chicken eggs, the main purpose of the incubator was to keep prematurely born babies warm by means of a warm water reservoir [4].

Over the years, incubator technology has come a long way. By means of new technologies and innovations in the field of medicine, infants can survive ever younger premature birth and overcome otherwise lethal diseases. However, from an aesthetics point of view, current incubators have not changed all that much. It is still a transparent "box", that, among others, keep the child warm and safe.

The reason for the transparent casing is obvious. In order to properly treat these fragile patients, nurses and practitioners should be able to observe the child. Research has, however, shown that the stimuli these children experience during their hospitalization has potential large adverse effects on the child's brain development [4][5]. Due to the large number of stressful and painful procedures, the brain of these small prematurely born babies is inhibited of proper development. Therefore, the MC has set the goal to design a new incubator mattress that will protect prematurely born babies from these adverse stimuli in the hope to ensure a more pleasant hospitalization experience by both parents and child.

C. Approach

In order to spice up the creativity within the MC, the decision was made to develop a design by using the "concept car" method. Although new in the medical environment, the "concept car" method is generally used in car industry. Through a 1:1 scale prototype, car designers show the company's vision of the future in car design and inspire other designers with new ideas [6].

Our design had similar goals in mind. The main goal was to ensure the future vision of the consortium's incubator bed design would be translated and visualized into a prototype. Furthermore, the goal was to ensure that no innovative ideas were lost or hindered in the process. Just like a concept car in car industry will never roll over our streets, our design was not meant to be inside an actual incubator.

In order to realize our design by means of the “concept car” method, a basic, but effective design cycle of various phases (analyze, synthesize, simulate and evaluate) was initiated and was executed in 2 months.

In the analysis phase, the problems and design opportunities expressed by the various partners in the consortium were gathered. These statements were to be used as input for the synthesis phase, within which various concept designs were realized. One concept design was then realized in the simulation phase and concluded with the 1:1 scale prototype.

In order to determine whether the “concept car” method would have the desired outcome, a presentation and discussion session with all partners was prepared.

In this paper we describe the design process within which we apply the “concept car” method. We then describe the final design and the realization of the 1:1 scale prototype. Finally the evaluation of the design by the MC is presented and conclusions are drawn based upon the feedback.

II. PROCESS

A. Analysis phase

In order to identify problems and possible design opportunities, interviews were conducted with all the partners within the consortium. By discussing their desires and opportunities on future development, vital information was gathered to function as a baseline for the design. By combining this input with the consortium’s original goal to develop a new incubator bed, the choice was made to focus on two main aspects within this design cycle:

1. Parent-Child bonding: specifically, the “approachability” of the child inside the incubator by parents.
2. Child comfort: the comfort of the sleeping environment for the child.

It was concluded that most of the partners found the physical acrylic transparent casing of the incubator very disturbing (it should be mentioned that as part o f the consortium there are also medical practitioners and nurses of the NICU). This physical barrier between parents and child is perceived as obtrusive and interruptive to the physical contact between parents and child.

Furthermore, the various partners expressed that it seemed unnatural to place a child that should be in a womb onto a flat mattress. Therefore, the second focus was put on the redesign of a more comfortable sleeping environment for the child. We chose specifically the sleep environment in order to provide a more open design space, relative to for instance emergency situations.

B. Synthesis phase

The second stage in the design process was the synthesis phase. In this phase, various ideas are generated and developed into the final concept. Due to the diversity of design experience within the consortium, a basic technique was applied in this phase. By first developing a large number of ideas (100) in a short period of time, it was believed out-of-the-box ideas were pushed forward. From these 100 ideas, 10 different design directions were distilled by means of grouping. Every group would then be molded into a concept resulting into 10 different concepts. Finally, of the 10 concepts 3 concepts were chosen by means of ranking of which one final concept would be developed further.

The final concept, called “womb environment” (Figure 1), consists of replacing the mattress inside the incubator with an “artificial womb” in which the child would stay. Key elements within this concept are:

- To keep the child’s movement restricted by presenting a flexible “womb”.
- To keep the child in a warm, dark and sound limiting environment, mimicking the womb
- To provide the child with a rounded bottom of the incubator in order to ensure a swinging movement of the whole womb.

Figure 1. Womb environment concept.

Before this concept could be developed into a prototype, various small developmental cycles were introduced. During these cycles, the “womb” idea was further developed. Next we will discuss the final design as a result from these cycles.

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III. FINAL DESIGN

1) CRIB

The final concept consists of two distinct products, an incubator bed and a mattress. The first product to be described is called the Child Rocking Incubator Bed or CRIB (Figure 2). This bed consists of two wooden shells that can rotate around each other by means of an elevated axis inside two side stands. This rotation allows the CRIB to be in two distinct positions.

In the first position, the child will lie on a mattress, inside the CRIB with the top shell rotated downwards, called the open position. In this situation, parents are invited to observe and interact with their child. Due to the use of wood, normally not present in incubators, the design provides a more homelike feeling expected to pull parents their attention away from the acrylic cover and more towards the inside of the incubator.

The final feature of the open position is the fact that parents can rock the bed inside the incubator, hence the name CRIB. The goal of this feature is to elicit a more natural, home-like interaction between parent and child. Just like a crib at home, parents can provide comfort to their child by means of rocking the bed. During this interaction parents can for instance decide to sing a lullaby to the child or talk to the child.

Figure 2. Closed (left) and open (right) position of the CRIB

Figure 3. Blanket over incubator

The second position possibility of the CRIB comes as a redesign of a practice performed in current day NICU's. In order to protect the child from external stimuli, such as light and sound, a blanket is nowadays placed over the incubator (Figure 3). During the design, we believed however that this blanket creates an even bigger barrier between the parents and the child, because the blanket completely restricts the observation possibility of the child inside the incubator.

As a solution to this problem, the CRIB design can be closed in one single motion towards the, so called, closed position. This will ensure that both light and sound will be restricted to the child just like the blanket. In order to provide parents and nurses the opportunity to still observe the child, a section of self-polarizing glass is implemented in the outer shell. This glass darkens by itself when light is shone onto it (like a pair of sunglasses), therefore, protecting the child automatically from excess light, but still enabling parents and medical practitioners to observe the child. Finally, the inside of the CRIB is outfitted with soft foam. This will allow the infants to push against the CRIB, just like they would experience inside their mother's the womb.

2) Comfort Mattress

In present day NICU's, snuggles and blankets are used in order to provide boundaries and position support for unstable babies. Especially when babies lay on their side, the limited muscle strength limits babies to maintain this posture on their own.

Figure 4. Comfort mattress

Based on the comfortable and movement restricting features of the womb, a Comfort Mattress design was proposed to be placed inside the CRIB (Figure 4).

The Comfort Mattress is an oval shaped mattress filled with silicone beads. These beads allow the mattress's shape to be flexibly molded. When the baby lies on the mattress, the silicone beads will shift and make sure the mattress adapts to the child's body shape.

Nurses are able to mold the mattress into boundaries and supports for the baby according to the baby's desired sleeping posture.

To approach the natural situation of skin-to-skin contact [7], the idea was proposed to make the surface of the mattress of a water proof, skin-like material (elastic, smooth, soft). This makes the cover easy to clean with alcohol, which saves the effort of washing the various sheets, blankets and cushions.

Wrapped in by a "skin" in a dark and rather closed sleeping environment with unobtrusive vital sign monitoring, it is expected to supply a comfortable and safe environment for premature babies within the NICU.

B. Simulation phase

As a final step in the design phase, both the CRIB as well as the Comfort Mattress were brought together into a working physical 1:1 scale prototype (Figures 5 and 6). The prototypes contained all the materials proposed in the design

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apart from the self polarizing glass and the skin-like mattress cover. These two features were, however, clearly explained during the presentation of the design to the consortium partners during the evaluation phase.

Figure 5. Prototype CRIB and comfort mattress

Figure 6. Prototype CRIB and comfort mattress

C. Evaluation Phase

In order to test the effect of the design, a presentation was set up for all consortium partners. The prototype was displayed in an NICU incubator together with a realistic and detailed picture presentation. By doing so, the NICU environment was recreated in order for everybody to transcend into the NICU atmosphere prior to presenting the details of the design itself.

The design was then presented through interactions with the prototype and an illustrative PowerPoint presentation. After the presentation, participants were invited to interact with the prototype, and in the meanwhile discuss the design. Finally the individual discussions were brought together in a group discussion concerning the presented design.

In order to test the effect of the design on the innovative and creative thinking of the participants, the different newly generated ideas and comments were documented and grouped together. The diversity of techniques used to generate new ideas were perceived as an indication to the effect of creativity generation among the partners.

IV. DISCUSSION

Below the various techniques observed to generate new ideas and innovations generated during the discussion are categorized, accompanied by examples.

A. CRIB discussion

1) Taking a feature and place it in context

The first category is based upon the fact that a feature was highlighted from the design and was developed further by placing it into context. An example is the self polarizing glass. The feature was not only perceived as useful, but the possibility was proposed to use it as an active indicator of environmental light conditions to parents and medical staff. The original idea behind the glass was only to protect the child from excess light in the NICU environment. However, as commented upon during the discussion, the glass could also be used to inform parents and or medical personnel there is simply too much light in the child’s environment. By doing so, they would become more aware of their environment and possibly undertake action to make it darker, hence more comfortable for the child. It was noted that this would also involve parents more in the care of their baby, giving them a foothold for something they can actively do as a means of care for their baby.

Furthermore, the function of the glass as an augmented information display was proposed. This display could indicate the health status of the baby while looking at the baby. The idea could potentially make the monitoring of the child more comprehensible for parents and more convenient for medical staff.

2) Taking a feature and build upon it

The second approach observed during the discussion is to take a feature of the design and further built upon it. An example of this can be related to the closed position of the top-shell of the CRIB design. Originally intended to passively protect the baby from external stimuli like sound and light, the idea was proposed to see what other functions could be added to the top-shell itself. “It might contain sensors to monitor the child” or “light therapy LED’s could be built into the shell”. This shows that interaction and shape can be an inspiration in itself to those who are unfamiliar to the prior design.

3) Turning critique into creativity

The third technique explains the moment where a point of concern was used as an inspiration for future innovation. One of the comments expressed by one of the medical practitioners was “that the design looked like an incubator inside an incubator, possibly creating an even bigger barrier between parents and their child". Although accepted by the design team this comment on itself provided inspiration for future development. Because what if the design would actually be an incubator inside an incubator? Due to its size this would mean that, if guaranteed to provide the required safety, the design could be used as a portable incubator. This would allow parents to walk around with their child inside the NICU ward, which would elicit whole new kinds of interactions between parents and their baby. It would for instance give parents much more freedom within the safety of the hospital. From a technological point of view, it would mean full wireless communication would be needed. Providing new opportunities and challenges for both designers and engineers. From this example, one can see that the physical presentation of a concept in the early stage of a design process can contribute greatly on the inspiration and development in future phases.

4) Would this concept really work in the NICU setting?

Apart from being nursed in the incubator, patients in the NICU may become ill and experience situations that the immediate access to the patient and institution of treatments (stimulation of breathing, resuscitation etc.) are indicated. In addition the performance of diagnostic procedures (Echocardiography, cranial ultrasound) in the incubator must be possible. In the next version of the CRIB mattress these considerations have to be taken into account.

B. Comfort Mattress Discussion

1) Where different disciplines meet – part 1

A topic of inspiration provided by the Comfort Mattress was the fact that the designers dared to make design decisions early on in the project. For instance if we consider the Comfort Mattress, during the design process it showed innovation was hard to realize in something so common as a mattress. The "half-egg" shape of the mattress design challenges the widely accepted flat configuration of everyday mattresses.

Although the idea behind the shape was welcomed and accepted by designers and engineers, concerns were expressed by medical practitioners. The question was put forward "whether the Comfort Mattress could cause asphyxia?" Since the autonomic motor ability of premature infants is not well developed, they are unable to push the supports away by themselves. This could make breathing difficult, especially when the child is in a lateral- or prone position.

This subject, asphyxia, was pointed out as a concern from both the medical practitioner's and mattress developer's side and was not presented earlier within the project, and, therefore, not seen as a potential problem. However, due to the presentation of the design, the subject is on the table.

2) Where different disciplines meet – part 2

The second topic concerning the Comfort Mattress was its cover material. Nowadays, babies don't lay immediately on the mattress, but on top of cotton sheets. The proposed cover has a skin-like feeling. From design and medical points of view, the child with frequent skin-to-skin contact has a more stable heartbeat and breathing rate [7][8][9].

However, it has to be investigated whether this skin-like material has similar beneficial effects to the baby.

To prevent liquids from damaging vital sign sensors inside the mattress and be easily clean, the cover was required to be waterproof by technical and medical staff. However, medical practitioners and the mattress developer gave their concerns on this subject: can the material also be breathable?

The answer to this question is considered beyond the scope of this paper. However, if we look at the large field of material innovation, the solution probably will not be so far in the future or even already existent.

C. Summary

To summarize, the overall impression of the various disciplines in the MC was quite positive. They agreed that the design contained most important elements that were gathered during the interviews. Furthermore, they believed the design is expected to elicit a better "approachability" of the child by the parents. Especially, the rocking of the bed was seen as a natural and intuitive approach of a small child.

Finally, the idea of converting a flat mattress into a 3D moldable mattress that fits the child's individual needs was seen as a great advantage. Since it has been shown that even these small patients need individualized care [10], this would further support in this hypothesis. From a design point of view the large amount of techniques used to draw inspiration from the design was perceived as successful. Since one of the original goals was to inspire future development within the MC.

V. CONCLUSION

Within a multidisciplinary consortium the decision was made to design and build an out-of-the-box, but plausible, incubator bed to be placed inside present day NICU incubators. The focus of this design was to enhance the sleeping comfort of NICU neonates and provide support to the bonding process between parents and their child.

The final goal of the design cycle was to develop a 1:1 scale "concept car" model of the final concept. This to ensure a visual and "experiencable" prototype could be presented to the full variety of partners in the consortium.

This model was presented to the various partners in order to receive critique and develop new ideas that could be used in the future design process.

During the discussion session, new interactions were developed, features inspired new ideas, lessons were learned from decisions that had been made, and teams learned from each other's expertise fields. Overall, this resulted in a thorough document of delight, appraisal and criticism greatly facilitating future design and development stages.

In general, it can be said that the CRIB and the Comfort Mattress, as they are presented now, will never see the light of day in an actual NICU. This, however, was also never the intention of the design, just like concept cars in car industry never get to drive on our streets. The main goal of inspiring fellow partners by means of a physically build 1:1 scale "concept car" prototype in an integrated design solution has shown its positive impact and will hopefully be used more in the field of medical design.

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Unobtrusive Physiological and Gesture Wearable Acquisition System: A Preliminary Study on Behavioral and Emotional Correlations

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***Abstract*—This study proposes an integrated wireless wearable system, that provides relevant information on gesture and electrodermal responses for affective communication investigations. The system is designed to be comfortable and unobtrusive to be used in immersive virtual realities as well as in actual scenarios in order to acquire implicit and explicit affective information. The system is comprised of a glove where textile electrodes, deformation sensors, and an inertial motion unit are integrated. The glove simultaneously acquires electrodermal activity and gesture, providing pre-elaborated signals that will be used for feature extraction purpose in emotion recognition filed. Preliminary results are reliable and promising for the complete integration of affective motion and physiological signal contents. This prototype is useful to investigate how humans perceive and produce affective interactions. Moreover, this prototype could be used for designing novel emotional models based on high-level and largely-comprehensive affective information.**

***Index Terms*—Gesture; electrodermal activity; affective recognition; textile-based systems; signal processing; features extraction; statistics;**

I. Introduction

In recent years, research on emotions [1], [2] increased, dramatically. In particular, the aspects related to how emotions can be elicited, measured and recognized are still open issues to be solved. One of the most interesting concepts under study is how a person can communicate an emotion nonverbally either alone or in a social scenario, where two or more people are interacting. Indeed, the evaluation and interpretation of physiological signals, facial expressions, body movements and postures present a strong challenge because of the many ambiguities related to affect definition, communication, and interpretation. Classical methods for evaluating affects tend to focus on questionnaires, in which the subjects are interviewed for reporting what they felt during the experiment, sometimes showing them a video of their performance, or asking them to recall what they felt at each moment during the earlier tasks [3]. Despite the promising results, in the majority of cases physiological signals and body movements are studied, separately. As matter of fact, previous studies showed that human movement is a visual stimulus and that we have experience of both perceiving and producing [4]. Concerning physiological signal evaluation for emotions recognition, many works have attempted to study physiological signals in order to extract parameters able to identify patterns which are related to specific emotions. Moreover, physiological reactions are one of the most reliable signs of an implicit affective response since they are controlled by the Autonomous Nervous System (ANS). In the literature, many works have provided evidence of the strong relationship between physiological reactions and emotional/affective states of humans [2], [5], [6]. In particular, the physiological signals used in the affect computing research are Heart Rate Variability (HRV), Respiration (Resp) and ElectroDermal Activity (EDA). Previous works in physiological signal-based emotion recognition are summarized in [7]. In our study, we propose the first integrated prototype for the simultaneous acquisition of gesture and physiological signals in the form of a textile glove that can acquire EDA, finger movements and that can also determine forearm orientation. Since EDA is the measurement of the sweat gland activity and is directly controlled by Sympathetic Nerve Activity (SNA), [8]–[10], it is considered an ideal way to monitor the ANS. EDA can be acquired at the palmar and fingers surface, because they are suitable anatomical sites of sweat eccrine glands. In the presented prototype, EDA is acquired by using textile electrodes placed on the index and medium fingers. Finger movements are collected by using textile deformation sensors placed on the glove metacarpophalangeal area and forearm orientation is acquired by employing an Inertial Measurement Unit (IMU) embedded in the glove electronics.

This works is split into two big sessions, as follows: the first one is named ”Materials and Methods” and the second one is the ”Conclusion”. Material and Methods is structured as follows: at the beginning, a description of the textile platform is reported in detail, afterwards, the study exposes through several sub sessions the principles and the methodologies of analysis for both the hand gesture detection (e.i., the first and second sub sessions) and the EDA (e.i. the third and fourth sub sessions). Afterwards, there are two sub sessions that are dedicated of reporting the experimental results on textile deformation sensors and wearable EDA tests. Finally, in the Conclusion session, the study results and improvements are underlined and a discussion is open on where and how these data could be integrated and used to improve the knowledge on the emotional communication system from a more high-level approach.

II. Materials and Methods

In this study, the first prototype of a multi-parameter sensing glove for the simultaneous acquisition of hand gestures and EDA is presented. EDA is acquired through dedicated textile electrodes integrated in the index and medium fingertip areas (see Fig. 1a). Finger movement is tracked by using five textile deformation sensors integrated in the glove metacarpophalangeal area (see Fig. 1b). Both EDA and deformation signals are acquired and elaborated on-line by using a dedicated wearable and wireless (i.e., ZigBee [11]) electronic unit. Moreover, forearm orientation is measured by an Inertial Measurement Unit (HMC6343 [12] by Honeywell) embedded in the glove electronics and fixed in the dorsal part of the forearm close to the wrist.

(a) EDA electrodes (b) Textile deformation sensors

Fig. 1: Multi-sensing glove prototype

A. Textile deformation sensors for hand gesture recognition

Textile deformation sensors and,more specifically conductive elastomer (CE) smeared sensors have been widely used for movement and gesture detection in neurorehabilitation [13]. Previous studies demonstrated the possibility of using a CE-based sensing glove to measure hand joint angles by using algorithms based on multivariate interpolation or neural networks. The drawbacks of these techniques was the high calibration effort, which limitated the use of such devices in practical situations [13]. Despite promising performances, CE-based prototypes showed several limitations such as non negligible relaxation time, non linearities and hysteresis [14]. Here, the gestural interface consists of five textile deformation sensors made of a particular conductive and elastic yarn. The same sensors were previously used for respiration monitoring in [15]. With respect to CE materials, this new sensor configuration was chosen for the better long term stability, the lower hysteresis and the faster relaxation time. The sensors have piezoresistive properties. Local fabric deformations due to user hand movements modify the sensor electrical resistance, and each sensor resistance is closely correlated with the single finger degree of flexion.

1) Processing methods: The sensor signal is characterized by a slow baseline drift due to the intrinsic characteristics of textile substrate (i.e., hysteresis and relaxation time are improved but they still exist). For this reason, an ad hoc algorithm for hand gesture recognition was conceived. The algorithm follows in real time signal local maximum and minimum levels through a peak detection routine that works without empiric thresholds. This continuous update of signal maximum/minimum allows for recognizing the condition of single finger opening or closing independently from the baseline variation (see Fig. 2). The combination of the described procedure on the five fingers enables a rapid recognition of the current hand gesture. With respect to previous methodology, no initial calibration is needed. This last point makes the algorithm flexible towards different hand physical configurations and glove sizes. In Fig. 2, the results of the developed

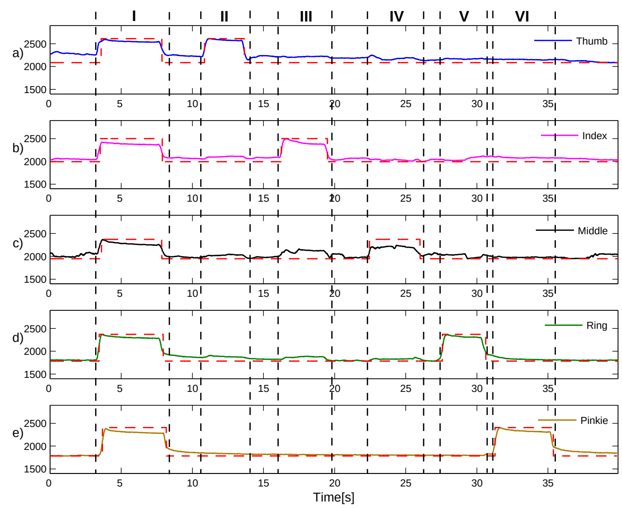

Fig. 2: Raw signals (solid lines) and algorithm results (dotted lines)

algorithm are shown. In each figure is represented the finger sensor signal (solid line) and the algorithm result (dotted line). In the case of high dotted line, the respective finger is flexed and vice versa. In this example, the user was asked to close the hand (Phase I) and then to flex one finger while the others are extended (Phase II to VI).

B. Textile electrodes for EDA monitoring

EDA is acquired by integrated textile electrodes placed at the fingertips. The use of textile electrodes as opposed to standard Ag/AgCl electrodes has already proven to be equivalent, as we reported in our study [16], where we performed the electrode characterization calculating the voltage-current characteristics and the electric impedance and found that their behaviors are comparable with standard electrodes. Moreover, the use of a wearable textile system exhibits several advantages in terms of portability and usability for long-term monitoring, and gives minimal constraints. In this prototype, the EDA is obtained as the ratio between an imposed continuous voltage of $0.5V$ between the two fingers and the passing current. Hereinafter, we refer to this EDA measurement as Skin Conductance (SC).

1) SC processing and features extraction: The SC signal is characterized by a tonic (i.e., Skin Conductance Level, SCL) and a phasic component (Skin Conductance Response, SCR). SCL is the slowly varying baseline level of skin conductance, while SCR arises within a predefined response window ($1-5s$ after stimulus onset), and is directly related to a given stimulus [17]. The signal division into its phasic and tonic components can be complicated by an overlapping of consecutive SCRs, in case of an inter-stimulus interval shorter than the SCR recovery time. In order to overcome this issue, we analyzed the SC by means of a modeling technique based on the deconvolution process [18]. The SC signal is the result of a convolution between the SNA and an Impulse Response Function (IRF). The IRF is a biexponential function the so-called Bateman function [19], which is the result of a diffusional model of the dynamics of sweat concentration in the corneum, assuming that it is governed by the laws of diffusion [20]. The decomposition of the SC in its components was performed by means of Ledalab 3.2.2. software package for MATLAB [21]. The row SC signal is pre-filtered by a lowpass filter with a cut-off frequency of $2Hz$. After this phase, a deconvolution between the filtered SC data and the IRF is performed. The deconvoluted signal was analyzed by a peak detection algorithm. A significant peak was detected if a local maximum had a difference greater than $0.2\mu S$ from its preceding or following local minimum [18]. The points under the threshold was considered part of the tonic driver signal. The tonic driver was estimated over the experiment duration time by an interpolation algorithm, and, consequentially, the tonic SC activity was achieved by a convolution between the tonic driver and the IRF. The phasic driver component was obtained by subtracting the tonic driver signal from the deconvoluted SC. In Fig. 3, an example of the original SC signal and the two deconvoluted tonic and phasic driver signals are shown. The extracted features from both phasic and tonic driver signals were the Number of Peak (NP), the MEAN value of the AMPlitude (MeanAmp), the MAXimum value of the AMPlitude (MaxAmp) and the MEAN value of the first derivative AMPlitude (DMeanAmp). The features were calculated within a window response of $5s$.

C. Textile deformation sensors tests

A set of experiments were carried out in order to test the performance of the sensor response and new algorithms of the sensing glovSeven participants were asked to perform different combinations of hand postures by performing finger flexion-extension movements while wearing the glove. Once a posture position was recognized (e.g., close thumb and open other fingers), the system generated the results of the finger combination. This operation was replicated three times for each user.

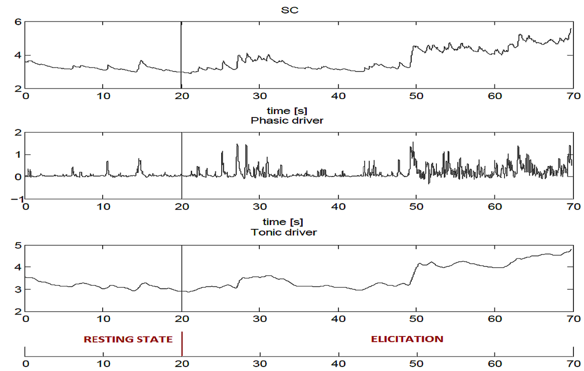

Fig. 3: Example of decomposition analysis. In the upper figure the row SC signal is shown. The lower figures report the deconvoluted tonic and phasic driver signals during resting and elicitation phase.

TABLE I: HAND POSTURE RECGNITION

Task	N Test	Recognized	No Recognized	Success
zero fingers	21	21	0	100
one finger	105	102	3	97.14
two fingers	210	199	11	94.76
three fingers	210	195	15	92.8
four fingers	105	97	8	92.38
five fingers	21	21	0	100

The results of this test are shown in the Table I. In this table, column*Task* represents the different configurations performed by the user, considering how many fingers are closed in that particular posture. Taking into account the first row of the table, *zero fingers* means that the user was performing the flat hand posture. Positive and negative recognition is reported in the third and fourth columns respectively. In the last column, the percentages are presented that represent the algorithms' capability of recognizing a particular posture.

D. Wearable EDA test

A preliminary test was carried out to evaluate the performances of the glove for affective evaluation. Seven patients were recruited and an affective stimulating protocol was administered. Affective elicitation was performed by projecting a set of images selected from the International Affective Picture System (IAPS) database [22], which consists of hundreds of pictures with an associated specific emotional rating in terms of valence and arousal. The valence and arousal ratings are based on several studies where subjects were requested to rank these images using the Self Assessment Manikin [23]. The protocol was divided into two sessions: basal, lasting 20 seconds and arousal, lasting 50 seconds. The first was a resting state phase in order to record the baseline of the subjects; the second session was characterized by a slideshow of images with an arousal level between $[5-6]$. The features extracted from the two sessions were compared by using statistical analysis. The statistical inference analysis was performed by means of a nonparametric test due to the non-gaussianity of the sample set. In particular, the data of subjects derived from the

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TABLE II: P-VALUE RESULTING OF A MANN WHITNEY TEST BETWEEN THE NEUTRAL AND AROUSAL SESSION

	NP	MeanAmp	MaxAmp	DMeanAmp
phasic	< 0.05	< 0.05	< 0.05	< 0.05
tonic	< 0.05	0.34	0.42	0.2

basal and the arousal session were compared by using Mann Whitney test [24]. The results of the analysis are shown in the Table II.

III. Conclusion

In this study, a preliminary test on the performance of a first integrated prototype for the simultaneous acquisition of gesture and physiological signals is reported. The novelty of the prototype lies on the use of a wearable textile glove integrated with different technologies enrolled in monitoring EDA and hand posture. Unlike previous textile-based sensing gloves for posture recognition, this glove employs new strategies using sensor integration into textile substrates. Moreover, the new implemented algorithm was able to distinguish the xconfiguration of each finger without any calibration stage or empiric threshold. Referring to EDA results, the textile electrodes integrated in the glove showed optimal capacity in detecting reliable signals (see Fig. 3). The results of the statistical analysis applied to the features extracted from the phasic SC component showed that calculated affective information was statistically significant for differentiating basal and arousal session. On the contrary, most of the features of the tonic signal did not show a statistical difference, which is most likely due to the short duration of the experiment, not allowing enough time for significant changes to be made in the slowly varying skin conductance level. These revelations create and interesting basis and open up promising novel research applications. The integration of gestural and physiological data could enable the use of EDA signal in real environments, allowing for the possibility of implementing innovative algorithms for the automatic filtering of movement artifacts that usually corrupt the electrodermal signals. Currently, it is well-known that EDA signals can only be used in strongly controlled conditions. Furthermore, the analysis of affective body language jointly to physiological signal interpretation can offer the possibility of both understanding how humans process emotional stimuli, [25], and allowing the implementation of innovative emotional models. It is worthwhile noting that, the integration of information coming from non verbal emotional expressions and physiological signals is widely advocated but rarely implemented [2]. It is a matter of fact that physiological and body language convey information about emotional states. However, current literature lacks the exact informational values given from these channels as emotional indicators. Even if oldest emotional expression research was focused on body language and posture, state-of-the-art affect detection systems have disregarded this information preferring facial expressions and acoustic-proposed features. However, it is a common experience that human body language is commonly used as a emotional communicative channel, therefore, gesture and posture together with direct sympathetic information, such as EDR, can offer a kind of integrated information that is often unavailable from the conventional nonverbal measures such as the face and paralinguistic features of speech. Although physiological signal interpretation is thoroughly studied in this field it is well know, that their emotional content is not sufficient enough in order to understand emotional communicative system. In this view, the recent advances in gestural interfaces, as that presented in this study, present an opportunity to study how advocate emotions, e.g., expressions and embodiments, activate physiological and behavioral responses during an emotional episode. According to our results we believe that new methodologies could hypothesize how these information cold be represented in specific models arising from the collaboration of affective and human-etology sciences giving weighted importance to all variables that can be simultaneously monitored by the wearable platform.

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Improving of Medical Imaging by the Use of Noninvasive Optical Technologies

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***Abstract*— Among the applied methods of tissue parameters measurement, a tendency to develop imaging methods based on detection and analysis of natural and forced biooptical phenomena is significant. Transmission variant of light-tissue interaction is considered in the paper. The work on the performed optoelectronic systems for human tissue transillumination is in progress. The transillumination image enables to disclose information on the functional condition, unavailable in the traditional X-ray technique. Preliminary results which were obtained by the authors during the finger and hand transillumination tests are promising. Some of them are presented in the paper. They show that effective imaging is possible even in a simple system and indicate that the further development of the designed noninvasive systems seems to be advisable.**

Keywords-medical imaging; light-tissue interaction; optical technologies; noninvasive transillumination

I. INTRODUCTION

In 1895, Wilhelm Conrad Roentgen [20] made the first radiogram of a hand, starting the development of image diagnostics methods. Other imaging methods appeared after a few dozen of years only. Modern imaging technology includes among others X-ray imaging, videoendoscopy, ultrasonography (USG), computer tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET) and thermography [1][2]. All these methods allow the detection of different properties of tissues through a variety of utilized phenomena. Particular techniques differ from the point of view of the advantages and disadvantages, a range of applications, degree of invasive or noninvasive interaction, patient ballast, and complication of procedures. For example, MRI has always been especially suited for vascular imaging.

The associated application of various methods is presently developed, allowing obtaining a more complete set of information on the object, compared to the tests made in one diagnostic technique only. Thanks to the selective optical properties of tissue cells, optoelectronic noninvasive imaging methods can be used for determination of essential features of tissue sets, particularly useful in developing combined diagnostics [3].

As far back as 1876, Karl van Vierordt [19] already observed changes in the solar spectrum transmitted by the finger tissues of his own hand. He discovered that after pressure causing inadequate blood supply, a change occurred in the spectrum composition obtained, which he related to the changing participation of oxygenated and reduced hemoglobins in the tissues. Information on the first attempts of transillumination with optical radiation appeared in 1929 [4]. In 1977, a hundred years after van Vierodt's observations, Minolta built the first oximeter based on the transillumination of the ear lobe. Fast development of such techniques, however, occurred in 1980's [5].

Due to strong scattering of the light, the practical implementation of optical transillumination for medical imaging is a difficult task [6–12]. This technology allows for supporting detection of pathological formations in some tissue sets, particularly those located on body perimeter. The subject of the presented work-in-progress is based on our own previous experience in an expanded use of the transmission photoplethysmography and pulse oximetry principles.

In Section 2, optical properties of human tissues are briefly mentioned. In Section 3, specific attributes of optical imaging and the proposed transmitting-receiving systems are described. Preliminary results related to transillumination images which were collected by us for human fingers and whole hands seem to be very promising. In Section 4, we present some selected results of imaging.

II. OPTICAL PROPERTIES OF HUMAN TISSUES

There is a window in which optical radiation can penetrate into human tissue set and propagate through it. This window includes red light and the NIR (Near Infrared) wavelengths [13][14]. A particular tissue composition depends very much on blood and water content what results in differences between values of optical parameters if to determine them at several compositions of various kinds and size. The effects of radiation influence on the object may concern its area and volume and the type of interaction largely depends on the properties of the beam of radiation. One of the most useful properties of using red and NIR wavelengths is that oxygenated hemoglobin and deoxygenated hemoglobin both absorb light differently in this region.

A given set of living tissues consists of many components which create the complex spatial configuration. When a biological object is exposed to selective illumination, we can receive the selective optical response to particular wavelengths. Depending on the locality and diameter of the light beam passing through the object the effects of light-tissue interaction can differ very much. The interactions occurring between the light and the tissues result

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in scattering, absorption and fluorescence, providing information on the structure, physiology, biochemistry and molecular functions. Optical imaging may be used for description of surface and volume structures.

III. Attributes of Optical Imaging

A. Powers and Limitations of Tissue Transillumination

Combined application of various methods simultaneously is presently developed, allowing for obtaining a more complete set of information on the object, compared to the tests made with one diagnostic technique only. In such an approach, tendency to develop noninvasive methods based on detection and analysis of biooptical signals phenomena is perceptible.

Transillumination is understood as the phenomenon of transmitting optical radiation with defined parameters by a given object, which becomes the carrier of information about the characteristics of this object. In case of biological objects, the optical properties of body fluids and other tissues are utilized. Photons in turbid media, such as most human tissues, are absorbed as well as scattered many times before being transmitted. Scattering and absorption can complicate the transillumination image. Due to the easiness of setting the location in relation to the measuring system and due to the variability of the optical properties, convenient objects in the transillumination tests are those located on body perimeter.

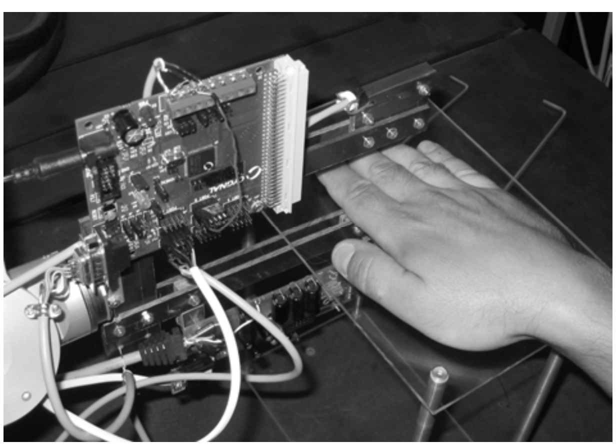
Under the noninvasive "transillumination" and "illumination from underneath", it is possible to diagnose and monitor the parameters of tissues and organs examined. It is related to achievements in optoelectronic devices and new capabilities of numerical processing.

Optical radiation that is to play the role of an effective information carrier should be sufficiently coherent and, due to the high optical density of the object, should also have possibly high intensity. However, for higher power density quantities, some destructive photothermal effects may occur. Wavelength and power of radiation selected improperly may not only act ineffectively, but may cause damage or destruction of the object.

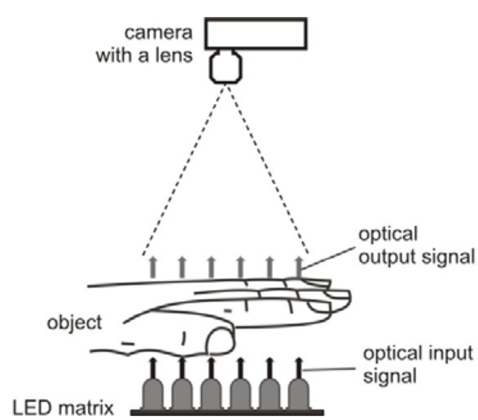
B. Transmitting-Receiving Systems

This paper includes a brief discussion of selected issues related to the biophysical and optical phenomena used and preliminary examples obtained by the authors with transillumination scanning applied to human hand and fingers. Our previous experience with measurements based on transmission pulse oximetry [15][16] has been utilized in an extended modified way. The basic application difficulty in an effective transillumination of thick tissue layers is the low power of radiation to be detected. Therefore, it is necessary to force the optical power of the source and to apply sensitive photodetectors. Various variants of systems were considered, however, always the high-efficient light emitting diodes LEDs were used as light sources. Two variants of these systems which we currently use are shown in Fig. 1a and Fig. 1b.

The experimental transillumination of hand and foot fingers is possible in a quite simple as well as efficient transmitting-receiving system presented in Fig. 1a. The mechanical structure of this system was constructed in the form of letter C [16][17]. The assembly is flexible and contains the motorization, brakes, motion transmission mechanisms, cable bundle, and pneumatic and electrical circuits. The optical part of the transmitting-receiving system consists of an illuminating LED diode placed opposite the sensitive receiving PIN photodiode (without the additional systems focusing the optical beam) which are fit at the structure ends in optical channels of 3 mm diameter and about 20 mm length. The object's scanning is made in a rectangular x-y coordinates system. A hand examined is laid on a transparent plate stabilizing its position. The hand should remain immobilized in relation to the scanning system. The immobilization may not disturb the object's function maintaining simultaneously the examined person's comfort.



(a)



(b)

Figure 1. Two variants of the performed measuring systems: (a) view of the scanning system where the input is the transverse motion of the system in relation to the hand fingers; (b) scheme of a system designed to study the transillumination effects with a monochromatic camera.

Scheme of another system variant is shown in Fig. 1b. The object transillumination is realized with a system consisting of hardware and program parts. The system makes it possible to study the transillumination effects in the optical range, including the visible and near infrared radiation (up to 1000 nm). The single and multi-element illuminating electroluminescent sources of light were tested. A monochromatic camera CMOS has been used as a light detector.

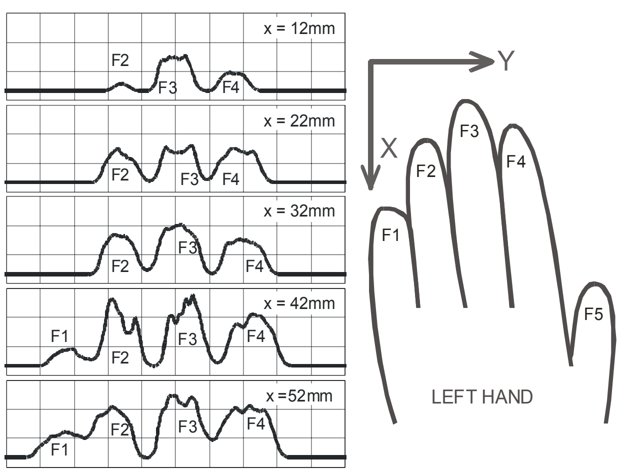
IV. EXAMPLES OF RESULTS

The selected results obtained with the system shown in Fig. 1a are presented in Fig. 2. The transverse motion of the scanning system in relation to the fingers was input. Several wavelengths were used for the tests. The results presented herein have been obtained for an ELJ-880-228B emitting light at the wavelength $\lambda = 880$ nm [18]. This LED was driven with current impulses. The PIN BPW24R photodiode was used as the sensitive photodetector.

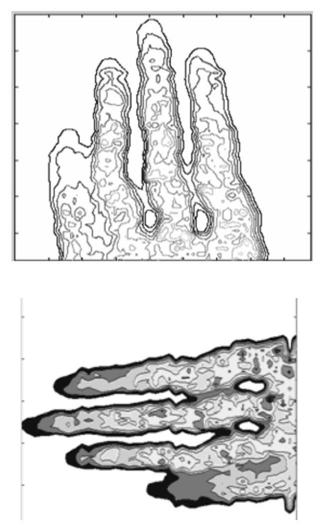
Fig. 2a presents the standardized values of the converted output signal from the photodiode for several x values. Particular levels of output signals show differences in light attenuation for a given position. The results obtained as transillumination images are shown in Fig. 2b. The grayness intensity is represented by the output signal values of the fingers examined (F1, F2, F3, F4). The specific isolines illustrate transmission properties of fingers at the used wavelength. Despite the system simplicity, the imaging obtained was as anticipated before. For example, differences between the amplitude variability for fingers without and with joint degeneration were observed.

Some examples of images observed with the system shown in Fig. 1b are presented in Fig. 3. It is possible to distinguish the structures of the object that occur sufficiently near the camera input surface. Thus, the observation of the internal structures is possible of such objects as hands, feet, etc.

Results of measurements shown in Fig. 2 do not still allow to distinguish the difference between the diseased and healthy joint because imaging of higher resolution has to be performed. However, results obtained with the system presented in Fig. 1b indicate that there is a possibility of optical detecting the pathological changes of joints.



(a)



(b)

Figure 2. Examples of imaging results obtained by the use the system shown in Fig. 1a: (a) Specification of the output signals dependency on the y location for selected cross-sections with x coordinate; (b) Examples of transillumination images obtainef for hand fingers.

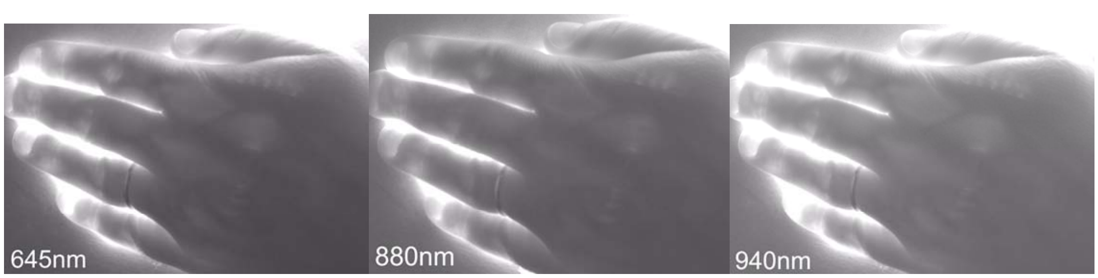


Figure 3. Comparison of results obtained by the use of the system shown in Fig. 1b for the left hand transilluminated from the palm side at three wavelenghts, respectively: 645 nm, 880 nm, and 940 nm.

Results presented in Fig. 3 show that transillumination of peripheral body sites is possible with red and near-infrared incident wavelengths. We may acquire not only the outlines of the object structure but also observe the blood vessels near the surface. Furthermore, there are visible bright components related to the finger joints. During studies, symptoms of rheumatic degeneration were observed. Strong light scattering by human tissues makes it hard to evaluate the structures occurring more deeply. The obtained images especially allowed the observation of the near-surface blood vessels and bone structures. The possibility of efficient transillumination greatly depends on the transmission properties of the object as well as the spectral characteristics of the LEDs and camera. The best effects were obtained for three wavelengths: 645 nm, 880 nm and 940 nm. All these wavelengths are included in the transillumination window where the hemoglobin species are the main light absorbers in arterial and venous blood [5]. Independently from the LED spectrum, the monochromatic camera allows obtaining of imaging in the gray scale.

From the diagnostic point of view, the improving advantages of the proposed method, compared qualitatively with, e.g., traditional X-ray imaging include:

- The lack of harmful influence of optical radiation of properly selected parameters on the human organism.
- The possibility of noninvasive continuous monitoring of the chosen parts of the body.
- The possibility of detecting the local concentration of the blood, e.g., hematoma.

V. CONCLUSION AND FUTURE WORK

The particular methods of medical imaging are not the alternative methods, but they can complement each other, according to the present tendencies to applying so-called combined imaging. The proposed optical imaging of such objects as the hand or foot has no the direct equivalent described in the accessible literature neither in the trade offer. It seems to be reasonable to test transillumination techniques not yet described in other reference data. The presented preliminary results of tests show that effective transillumination scanning is possible even in a simple system and indicate that the further development of the developed measuring system is appropriate and justified. The applied technique can be the useful tool in the process of diagnosing of, e.g., surface blood vessels and the rheumatoid inflammation of joints. From the combined imaging point of view, the optical imaging may provide information on the functional condition unavailable in other techniques. Transillumination imaging has the lower resolution in the comparison with, e.g., the RTG techniques, but they allow to detect changes invisible on the X-ray pictures. We have concentrated our current works on developing efficient transillumination of thick layers of tissues and building algorithms representing the anatomic and functional properties.

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Introducing the Global Advocacy Leadership Academy (GALA): Training Health Advocates around the World to Champion the Needs of Health Care Consumers

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***Abstract*—Patient advocacy can make significant contributions to health research by ensuring that efforts are patient-focused and help promote cooperation between all relevant sectors of the health care community. Yet, the development of effective patient advocacy organizations demands strong leadership, establishment of active collaborations with key stakeholders, and careful management of fiscal and personnel resources to enhance health outcomes. This presentation describes the development and implementation of an innovative training academy to prepare cancer advocacy leaders, both domestically and internationally, by helping them carefully consider strategic health advocacy processes, roles, and responsibilities. The Global Advocacy Leadership Academy (GALA) will provide participants with a comprehensive overview of the modern health care system, identifying critical constituents and stakeholders, and examining interrelationships between key individuals and organizations. Strategies for fostering meaningful communication, cooperation, and coordination between patient advocacy organizations and other stakeholders related to health, including consumers, other advocacy groups, clinicians, government officials, researchers, and private industry representatives, will also be explored. For example, patient advocacy organization leaders will learn about communication strategies for working effectively with researchers and clinicians to support prevention, detection, treatment, and survivorship efforts that will benefit patients. Patient advocacy organization leaders will also explore strategies for raising funds and increasing funding for health research. They will learn about clinical research, health regulatory systems, community organizing, as well as drug and technology development and approval processes from basic research to clinical practice. Exemplar models of successful patient advocacy organization leadership will be described and evaluated as GALA case studies that illustrate effective health advocacy.**

Keywords-patient advocacy organizations; leadership; media relations; corporate relatioms; health care systems; government agencies; stakeholders; personnel management; health promotion.

I. INTRODUCTION

The Global Advocacy Leadership Academy (GALA) is a new public health educational initiative designed to facilitate needed training and support for leaders of health advocacy

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organizations around the world. Leadership of health advocacy organizations is a complex enterprise that demands a tremendous amount of specialized knowledge about the health care system and constituent groups, adaptability to evolving health care systems, and the ability to reach, influence, and collaborate with a wide range of individuals from different sectors of the health care system through strategic health communication. The GALA program is introducing a unique international training and support model to prepare health advocacy leaders to meet the challenges of building and sustaining strong consumer advocacy organizations to champion the needs of patients and their caregivers within the modern health care system.

Effective leadership of health advocacy organizations is a demanding and complicated enterprise. While many aspiring advocacy organization leaders are passionate about helping to improve the modern health care system and to represent the needs of health care consumers, they may not be particularly well prepared to meet the demands of achieving these goals. The development of the GALA program grew out of the work of its founders (Gary Kreps and Paula Kim) in advising new health advocacy leaders from around the globe to achieve their goals. We recognized the many challenges that advocacy leaders face in influencing health research, health care practices, and health care policies and decided the best way to assist these leaders was to develop a formal system (GALA) for building advocacy organization leadership capacity. Moreover, we realized that health advocacy organizations were situated within a global health care system, concerning many of the same health care problems that affect consumers around the world. There was a tremendous need to link health advocacy organizations within a global advocacy network to promote international cooperation and collaboration for achieving shared goals of consumer empowerment and support within an interdependent, challenging, and evolving global health care system [1]. This paper outlines the goals and strategies of the GALA program for supporting the development of effective and influential health advocacy leaders and organizations.

II. Meeting Health Advocacy Challenges

The GALA program is designed to help leaders understand the unique sociopolitical structure of the modern health care system, both on a broad societal level and also within the unique health issue communities that address the specific areas of direct interest to different health consumer groups (for example, communities interested in lung cancer, diabetes, Lupus, kidney transplantation, hemophilia, or other challenging health issues). Strong and effective health advocacy organization leaders need to understand the lay of the land within the rapidly evolving health care system so they can help influence health care policies and practices to reflect the needs and goals of the health care consumers they represent.

Health advocacy leaders also need to know which specific organizations and individuals exert influences in the delivery of care, development of health policies, conduct of health research, and translation of research into health practices within the health domains in which they want to support the needs of consumers. Effective leaders must build collaborative relationships with key organizational representatives to exchange relevant information and cooperate on issues of importance to consumers. There is a daunting amount of information to learn to prepare for effective advocacy group leadership and a vast number of relational connections to establish for new advocacy leaders. Often, new health advocacy leaders have serious information deficits and limited relational connections that limit their abilities to accomplish important consumer support goals.

The GALA program is introducing new and relevant training, support, advising, and collaboration training programs to help health advocacy leaders build their knowledge base and learn how to work effectively with key representatives of different segments of the health care system. GALA will help connect advocacy leaders to relevant health researchers, educators, government and regulatory agency officials, health care delivery system personnel, health product and services corporation leaders (pharmaceuticals, health equipment, medical devices, insurance companies, and health informatics firms), media, representatives, as well as leaders of other related advocacy and support organizations. Not only is the GALA program designed to teach leaders about these different relevant segments of the health care system, but the GALA program will introduce health advocacy leaders to key representatives of these health sectors to initiate development of cooperative relationships for achieving advocacy goals.

The GALA program is also designed to help educate advocacy leaders about the nature of health research, including how research is funded, who conducts health research, how research results are reported, how to make sense of health research findings, and how research is translated into relevant health care policies and practices. The GALA program will help advocacy leaders understand the intricacies of the modern health care system, including the design of health care delivery systems, the key roles performed by different professionals and support personnel working within the health care system, and the evolving policies governing health care delivery and reimbursement. The GALA program will also educate advocacy leaders about the development of government legislation for health care policies, programs, and research, corporate influences on the health care system, and the unique roles performed within the health care system by professional associations, regulatory agencies, educational institutions, support organizations, foundations, and other assorted non-profit, for-profit, and government agencies.

III. Health Information Demands

Access to and effective use of relevant, accurate, and timely health information is critically important for guiding the important health-related decisions that consumers and providers must make across the continuum of care to

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promote health and well-being [2]. This includes decisions about the prevention of health risks, health promotion behaviors, the detection and diagnosis of health problems, health care treatment strategies, and best practices for living with health threats (successful survivorship) [3]. Yet, health information is complex, with many different kinds of health risks, each with different causes, stages, symptoms, detection processes, and treatment strategies. Health care knowledge is rapidly evolving with advances in research and applications concerning etiology, prevention, detection, diagnosis, and treatment of health problems.

Health advocacy organizations have the potential to help break through the complexity of health and health care by disseminating relevant, timely, accurate, and clear health information to consumers to help guide informed health decision making. However, there are significant barriers to the dissemination of health information, especially for at-risk populations, due to limited access to health information, health literacy challenges, limited education levels, and the complexity of health research and health care processes [4]. The GALA program is designed to help health advocacy leaders develop a wide range of necessary knowledge and skills to enable them to achieve important consumer goals. For example, GALA can help health advocacy leaders learn how to support the information needs of the health care consumers they represent, providing these consumers with access to relevant, timely, and accurate health information. The GALA program is also designed to help advocacy organization leaders learn how to promote and advocate for increased funding for relevant health research needed to improve prevention, detection, treatment, and survivorship for the consumers they represent.

The GALA program will help leaders learn how to run effective advocacy organizations to serve the needs of their constituents and influence health practices. Strategies for recruiting, mobilizing, and serving the needs of organizational volunteers and personnel will be examined. Fund raising, investment, and fiscal management demands will be carefully examined. Strategies for using funds wisely for disseminating information, influencing legislation and policies, and planning and implementing influential health campaigns will also be examined.

The GALA program will help advocacy organization leaders learn how to disseminate relevant health information through a variety of media to raise awareness and educate health policy makers, health care administrators, providers, and consumers about the health issues of concern to their constituents. The GALA program will help advocacy organization leaders learn how to lobby legislators, regulators, and health care administrators to improve health care policies and practices. The health advocacy leaders will learn how to provide needed support and assistance to consumers confronting challenging health care problems, as well as to support the needs of their caregivers, family members, and loved ones. Perhaps most importantly, the GALA program is designed to promote local and global cooperation within the health care system to support health promotion, prevention, early detection, the best treatments, and successful survivorship for the health issues of concern to their constituents.

IV. THE UNIQUE GALA DELIVERY MODEL

The GALA program is designed to provide advocacy leaders with relevant information and strategies for working effectively with key internal and external groups. For example, training programs will be conducted concerning development of effective relationships and collaborations with media representatives, government representatives, corporate leaders, researchers, and health care system representatives. Moreover, the GALA program will provide advocacy leaders with ongoing information support, consultation, updates on new opportunities/constraints, and continuing education to meet changing needs and refine advocacy knowledge and skills.

GALA programs will be delivered in several different complementary ways. Advocacy leaders will be invited to attend training programs conducted at a centralized site (George Mason University), where they will also be introduced to relevant government, corporate, and health care system representatives, researchers and scientists, legal, fiscal, and administration advisers, campaign planners and fundraising experts, as well as experienced and successful health advocacy group leaders. In addition to centralized training programs, GALA program educators will travel to advocacy organizations in different parts of the world to provide on-site training programs. Arrangements will be made on demand to provide individual follow-up personal consultation with advocacy leaders to address specific emergent issues and concerns. Field experience opportunities will also guide advocates to participate in important meetings, conferences, and other relevant events, as well as to examine with GALA personnel the implications of these meetings. GALA is also proposing to link advocacy leaders and their constituents with an online information system (a collaboratory) to provide continuous support, on-line educational modules, repositories of health information documents, case studies, and media, as well as networking/collaboration opportunities for solving problems and developing new health advocacy initiatives.

The GALA training programs will model effective health advocacy leadership strategies. Leaders will learn how to establish and build effective advocacy organizations. They will learn how to recruit volunteers, organization members, and support staff. They will develop strategies for collaborating with other advocacy groups, locally, nationally, and internationally. They will develop skills for establishing working relationship with government representatives, corporate leaders, media representatives, educators, and researchers. They will also learn how to raise, manage, and invest funds for achieving advocacy goals.

The global nature of the GALA program is designed to promote international cooperation and collaboration for

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addressing advocacy issues, sharing resources, and implementing new policies and practices within the health care system. Advocacy leaders from different parts of the world who may be addressing similar issues will be linked to share information and resources for addressing these common issues. These leaders will be encouraged to build international collaborations for influencing global health practices and policies. The GALA program will combine support for leveraging research, theory, policies, and innovative applications to promote development of robust and adaptive advocacy programs to support the needs of health care consumers and their caregivers.

V. GALA DEVELOPMENT ACTIVITIES

To promote the growth and development of the GALA program, new strategies are being examined for seeking government and corporate support for GALA training and outreach programs. Survey data are being collected from key members of the advocacy, health care, government, and corporate communities to expand understanding about the unique training needs of advocacy organization leaders and the best strategies for meeting these training needs. GALA team members are identifying leading experts to work with the program to serve as mentors and trainers for aspiring advocacy leaders. New training modules, educational materials, and instructional guides are being designed and refined to use with the program. The GALA online collaboratory system is being designed and information is being collected to include in the collaboratory's online repository of documents, case studies, articles, research and funding opportunities, advocacy resources, and media programs. Information about the GALA program is being disseminated to key individuals and organizations around the globe to increase awareness and support for the new and exciting GALA health advocacy leadership activities.

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Detecting depression using a multidimensional model of emotional states

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***Abstract*—Depression is a major problem in our society. It causes great pain and suffering for patients and their families. The purpose of this study is to detect persistent negative emotions for early detection of depression using physiological sensors. Therefore, we develop an automatic depression prevention tool using an algebraic model of emotional states. This algebraic model provides to represent emotions and provides powerful mathematical tools for the analysis and the processing of these emotions. It consists of representing and detecting negative emotions. Experiments show the efficiency of the proposed method in detecting negative emotions by giving high recognition rate.**

Keywords-depression; algebraic representation ; negative emotions; physiological signal.

I. Introduction

Negative emotions (anxiety, fear, anger, and grief) may affect physical health and the quality of life. Indeed, people with depression experience severe and prolonged feelings of negative emotions like sadness, anger, disgust and fear. Depression is a common yet serious illness. It is a common problem that carries a high burden of suffering. In fact, the inability to diagnose clinical depression early, can have a serious impact on suffers, including the risk for suicidal ideation. Thus, Gotlib and Hammen [1] and Chynoweth et al. [2] demonstrate that most suicides are linked to depressive disorders and symptomatology. Depressed individuals experience prolonged periods of hopelessness, anger, guilt, desperation and a tendency to suicidal thoughts. Studies suggest that effective treatments for depression which may be aided by the detection of the problems in its early stages. In this context, and as part of GERHOME project [3], we aim to develop an automatic health care system that would assist mental health professionals by providing early warning-signs indicating whether a patient is likely to be depressed through their emotional states. The objective of GERHOME project is to create a research infrastructure that will enable experiments with technologies for improving the quality of life for the elderly. In fact, older adults generally want to be treated at home and with as little pain and discomfort as possible. Therefore our tool can be integrated in smart home (SH) in order to prevent depression and detect the mood disorders. For this, we use physiological signals to detect specific emotions and then to prevent depression. More physiological parameters can be measured directly by wearable sensors or can be derived from the analysis and correlation of different signals. For example, we can use a watch or a bracelet to capture the heart rate, an earring for Blood Volume Pulse and a shoe for the skin conductivity [4]. Therefore, our system permits to improve the quality and efficiency of health care at home by preventing depression. It is based on an algebraic model of emotional states [5] and it consists of representing and detecting of persistent negative emotional states.

The remainder of this paper is organized as follows. In Section 2, we defines depression and then we give an overview of related works on human emotion research. In Section 3, we describe our model to represent emotions. In Section 4, we describe our method of detection of negative emotion based on physiological signal and we conclude in Section 5.

II. Depression and Descriptive Schemes for Emotions

In order to detect depression, our method is based on detecting negative emotions. In this section we defines depression and then we give an overview of related works on human emotion research.

A. Depression

Depression and anxiety disorders are highly prevalent worldwide. Statistics demonstrate that approximately 150 million people suffer from a major depressive disorder at any moment, and almost a million commit suicide each year [1] [6]. Depression is defined in medical dictionaries as a physiological and metaphorical lowering of emotional function. Someone with depression experiences extreme sadness or despair that lasts for at least two weeks or longer. Indeed one of the features of major depression is not that people have negative reactions to negative situations, it is that they cannot pull themselves out of those negative emotional moods [7]. Our goal is to detect persistent negative emotions in order to prevent depression.

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B. Descriptive Schemes for Emotions

An emotion is the consequence of a feeling or the grasping of a situation and generates behavioral and physiological changes. Emotion is a complex concept. Darwin [8] said that emotional behavior originally served both as an aid to survival and as a method of communicating intentions. He thought emotions to be innate, universal and communicative qualities. Ekman [9], Izard [10], Plutchik [11], Tomkins [12] and MacLean [13] have developed the theory that there is a small set of basic emotions out of which all others are compounded. The most famous of these basic emotions are the Big Six, used in Paul Ekman's research on multi-cultural recognition of emotional expressions [14]. The Big Six emotions are happiness, sadness, fear, surprise, anger and disgust. According to research in psychology, two major approaches to affect modeling can be distinguished: dimensional and categorical approach. The dimensional approach models emotional properties in terms of emotion dimensions. It decomposes emotions over two orthogonal dimensions, namely arousal (from calm to excitement) and valence (from positive to negative) [15]. The second approach posits a finite set of basic emotions which are experienced universally across cultures (e.g., Plutchik [11], Tomkins [12], Ekman [9], etc) . In our study, we opted for Plutchik approach as the basis of our model and will thus describe it in details.

1) Plutchik model: Robert Plutchik proposed a three-dimensional "circumplex model" which describes the relationships between emotions. He proposed eight primary emotion dimensions arranged as four pairs of opposites [11]: (Joy-Sadness, Fear-Anger, Surprise-Anticipation, Disgust-Trust). The vertical dimension represents intensity or level of arousal, and the circle represents degrees of similarity among the emotions. He suggested that non-basic emotions are obtained through the addition of basic emotions (color analogy, Plutchik, 1962) [16]. In his model, for instance, remorse = sadness + disgust and contempt = disgust + anger. Plutchik defined rules for building complex emotions out of basic ones. In practice, combination of emotions follows the method "dyads and triads" [17]. He defined the primary dyads emotions as the mixtures of two adjacent basic emotions. Secondary dyad includes emotions that are one step apart on the "emotion wheel", for instance Fear + Sadness = Despair. A tertiary emotion is generated from a mix of emotions that are two steps apart on the wheel (Surprise + Anger = Outrage).

III. THE PROPOSED EMOTIONAL MODEL

In this section, we present our approach of modeling emotional states. Indeed, the proposed model is different from traditional approaches like ontological representation. It is based on an algebraic representation using multidimensional vectors. We represent every emotion as a vector in a space of 8 dimensions where every axis represents a basic emotion. This multidimensional model provides the representation of an infinity of emotions and provides also a powerful mathematical tools for the analysis and the processing of these emotions. The proposed model is similar to the RGB colors representation model which is based on three basic colors (Red, Green, Blue) to build all the others ones. For example, blue and yellow paints mix together to create a green pigment. In order to develop this analogy, it's necessary to define the basic emotions. For this, we will adopt the Plutchik definition of basic emotions which is a very intuitive and easy model including the idea that complex emotions are obtained by mixing primary ones. This last property is very important on our model because it allows us to define an infinity of combinations using the eight basics emotions defined by Plutchik.

A. Definition

The proposed model consists on the representation of emotions using multidimensional vectors. We represent every emotion as a vector in a space of 8 dimensions where each axis represents a basic emotion. First, we define our Base by (B) = (joy, sadness, trust, disgust, fear, anger, surprise, anticipation). So, every emotion (e) can be expressed as a finite sum (called linear combination) of the basic elements.

$$(e) = \sum_{i=1}^{8} \langle E, u_i \rangle u_i \tag{1}$$

thus, $(e) = \alpha_1 Joy + \alpha_2 sadness + \alpha_3 trust + .. + \alpha_7 Surprise + \alpha_8 anticipation$
where α_i are scalars and $u_i (i = 1..8)$ elements of the basis (B). Typically, the coordinates are represented as elements of a column vector E

$$E = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ . \\ . \\ \alpha_8 \end{pmatrix}_B$$

where $\alpha_i \in [0, 1]$ represents the intensity of the respective basic emotion. More the value of α_i get nearer to 1, more the emotion is felt.

In linear algebra, a basis is a set of vectors that, in a linear combination, can represent every vector in a given vector space or free module, and such that no element of the set can be represented as a linear combination of the others. We have demonstrate that (B) satisfies the spanning property and the linear independence property [5]. Thus, we proved that (B) = (joy, sadness, trust, disgust, fear, anger, surprise, anticipation) is a linearly independent spanning set.

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B. Representation of basic emotions

A vector represents a basic emotion if it verifies the following property:

$$\forall i \in [1..8], \exists \alpha_i \ with \ \frac{\alpha_i}{\sum_{i=1}^{8} \alpha_j} = 1 \qquad (2)$$

A basic emotion is described by a vector which contains a single non-zero coefficient. The following vectors represent some basic emotions:

$$E_{disgust} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ \alpha_4 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}_B \quad E_{sadness} = \begin{pmatrix} 0 \\ \alpha_2 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}_B$$

where $\alpha_4, \alpha_6 \neq 0$

The proposed model takes into account the property of the intensity of the emotion. Indeed, each emotion can exist in varying degrees of intensity. The coefficients α_i determine the emotion intensity. According to the value of the coefficients α_i we can make the difference between annoyance, anger and rage or pleasure. So, rage is the basic emotion anger with high intensity. The multidimensional model provides the representation of an infinity of emotions and provides also a powerful mathematical tools for the analysis and the processing of these emotions. Indeed, we can apply the usual basic algebraic operations on vectors like the addition, the scalar multiplication, the projection and the distance in an Euclidean space. We are going to detail only the addition. For more details, you can see [5].

C. Vector addition

We have seen in the previous paragraphs that the mixture of pairs of basic emotions resulted of complex emotion. fear and sadness for example produce the complex emotion "despair". "envy" is a mixture of sadness and anger. In this part we define the combination between emotions as the sum of two emotion vectors. This addition is defined as the maximum value of coefficients (term by term). Let E_{1u} and E_{2u} be two emotional vectors expressed in the basis (B) respectively by $(\lambda_1, \lambda_2, .., \lambda_8)$ and $(\lambda_1^{'}, \lambda_2^{'}, .., \lambda_8^{'})$. The addition of these two vectors is defined as:

$$E^{'} = E_{1u} \bigoplus E_{2u} = \max(\lambda_i, \lambda_i^{'}) for 0 \leq i \leq 8 \qquad (3)$$

In this sense, the vector representing the emotion despair, which is mixture of fear and sadness, is defined as:

$$E_{despair} = E_{fear} \bigoplus E_{sadness}$$

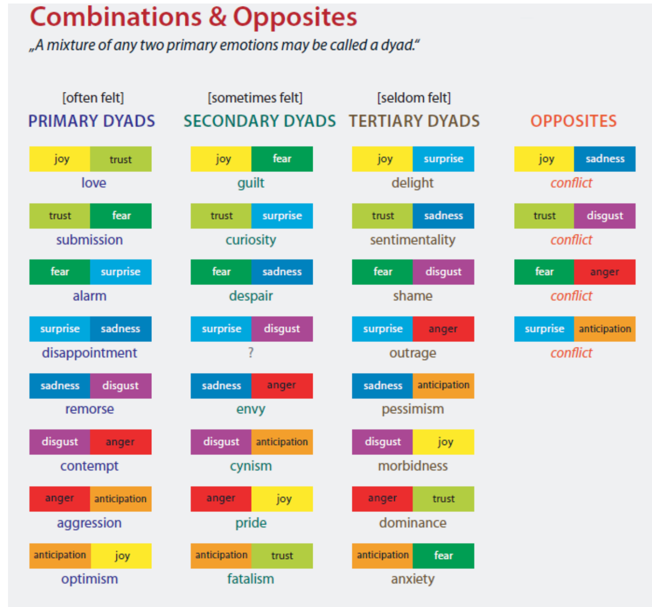

Figure 1. Combination and opposites on the Plutchik's model

$$E_{despair} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \alpha_5 \\ 0 \\ 0 \\ 0 \end{pmatrix}_B \bigoplus \begin{pmatrix} 0 \\ \alpha_2 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}_B = \begin{pmatrix} 0 \\ \alpha_2 \\ 0 \\ 0 \\ \alpha_5 \\ 0 \\ 0 \\ 0 \end{pmatrix}_B$$

where $\alpha_2 \neq 0 \ et \ \alpha_5 \neq 0$

In the same way, we can obtain the "vector form" of the other complex emotions states defined by Plutchik. These emotions combinations are shown on (Figure 1).

IV. METHOD OF DETECTION OF NEGATIVE EMOTIONS

In our study, we explore the use of physiological signals for detecting persistent negative affects. We elaborate an emotion recognition method from Physiological Data based on signal processing algorithm. Our method permits to recognize emotion composed of several aspects like simulated and masked emotions. The data used for this study comes from the data collected in the MIT Media Lab: Affective Computing Group [18]. MIT's data set comprised four physiological signals, obtained from the masseter muscle (EMG), blood volume pressure (BVP), skin conductance (GSR) and respiration rate (RESP) collected over a period of 20 days, concerning eight emotions: the neutral state, anger, hate, grief, platonic love, romantic love, joy and reverence.

Our approach is composed of two modules: training module and the recognition module. In the training module, feature vectors are extracted from emotion training patterns. In the recognition module, classification has been performed by using the K-Nearest Neighbor algorithm. The result is a 8 component vector representing the detected emotion. This

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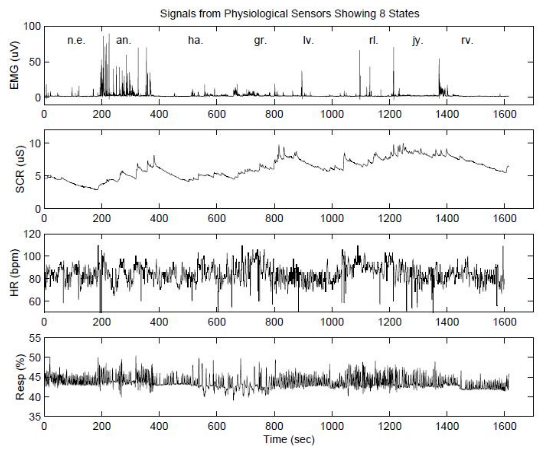

Figure 2. An example of a session data collected from four sensors [18]

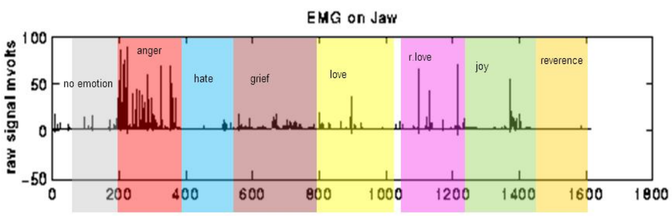

Figure 3. Segmentation of the signal by emotion

vector is transformed to XML data thanks to the three layer model [19]. Let us here present the two modules of the proposed emotion recognition method.

A. Training module and features extraction

This session explains the proposed method to collect training data. Our newly developed method is based on feature extraction using signal processing techniques. The data consist of 25 minutes of recording time per day over a period of 20 days. Each day includes 4 signals showing 8 states in the order: the neutral state, anger, hate, grief, platonic love, romantic love, joy and reverence (Figure 2). Healey's original data was sampled at a rate of 20 samples per second, creating a digital version of the signal [18]. The signal processing for each sensor, include isolation of each emotion, smoothing, peak detection and features extraction (c.f. Figure 2). The global scheme of the features extraction is given by Figure 4. Firstly, we segmented the data, according to the emotions elicited at corresponding time frames (for example, although the recording time was 25 minutes, we only used the data from the time frame when the appropriate emotion (e.g., anger) happened). Let A designates the samples taken from any one of the eight emotions and any one of the four sensor (e.g., emotion anger, sensor: EMG). We process each appropriate emotion data separately to extract 30 representative vectors for this emotion. This is done by applying 3 major steps. First,

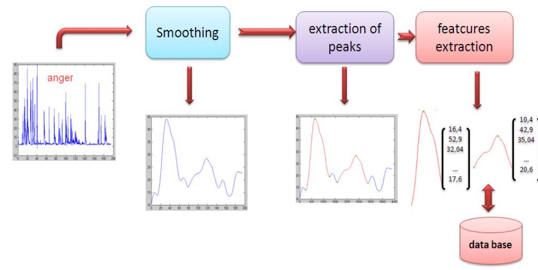

Figure 4. The global scheme of the features extraction module

we smooth the signal to reduce its variance and facilitate the detection of its maxima and minima. That is why we apply Hanning window (smooth curve) [20]. Secondly, we compute the gradient of the signal and we apply the zero-crossings method to detect the peaks. Thirdly, we extract features for each emotion by computing typical statistical values related to peak, such as mean value, standard deviation, the amplitude and the width of peak. These data will be stored in a vector (the emotion feature vector) which corresponds to the appropriate emotion. Thus, we built an emotion training data base composed by 240 vectors representing the eight affective states.

B. Recognition module

The recognition module consists of two steps: (i) features extraction to have test data set and (ii) classification. Test data set was done by using similar steps to the training data, except that it does not have the emotion information. However, we used the K-Nearest Neighbor algorithm (KNN) [21] to classify an instance of a test data into an emotion classe. Infact, K-Nearest Neighbor (KNN) classification is a powerful classification method. The key idea behind KNN classification is that similar observations belong to similar classes. Thus, one simply has to look for the class designators of a certain number of the nearest neighbors and sum up their class numbers to assign a class number to the unknown.

In practice, given an instance of a test data x, KNN gives the k neighbors nearest to the unlabeled data from the training data based on the selected distance measure and labels the new instance by looking at its nearest neighbors. In our case, the Euclidean distance is used. The KNN algorithm finds the k closest training instances to the test instance. Now, let the k neighbors nearest to x be $N_k(x)$ and $c(z)$ be the class label of z. The cardinality of $N_k(x)$ is equal to k. Then the subset of nearest neighbors within class $(e) \in$ the neutral state, anger, hate, grief, platonic love, romantic love, joy and reverence is

$$N_k^e(x) = \{z \in N_k(x), c(z) = e\} \tag{4}$$

We then normalize each $N_k^e(x)$ by k so as to represent probabilities of belonging to each emotion class as a value between 0 and 1. Let the lower case $n_k^e(x)$ represent the normalized value. The classification result is defined as linear combination of the emotional class.

$$e^* = \sum < n_k^e(x), e > e \tag{5}$$

Thus,

$$\begin{aligned} e^* = n_k^{noemotion}(x)\ noemotion + n_k^{anger}(x)\ anger \\ +... + n_k^{joy}(x)\ joy + n_k^{reverence}(x)\ reverence. \end{aligned} \tag{6}$$

Thus, we build a probability model for each emotion class where $n_k^e(x)$ represents the probability of the respective emotion class. For example, if k = 10 and 8 of the nearest neighbors are from emotion class $anger$ and the other 2 are $grief$, then emotion class $anger$ has an intensity value of 0.8 ($n_{10}^{anger}(x)$ =0,8) and emotion class $grief$ has an intensity value of 0.2 ($n_{10}^{grief}(x)$=0.2). The classification result is defined as: $(e^*) = 0.8anger + 0.2grief$. Thus, our recognition method builds a probability model for each class and permits to recognize emotion composed of several aspects. Therefore, we get all the information on the emotion. This representation can be transformed, therefore, to the generic computational model of emotional states defined on Section 2 by applying the transformation matrix. Thus, we obtained eight emotional vector expressed in the basis (B). Then, we applied Plutchik's rules (c.f. Figure 2) to generate a data base of emotion for use at a later time. For example, grief is the basic emotion sadness with high intensity. Therefore, we can generate the emotion vector sadness. Either, we can generate the emotion vector "guilt" by combining joy and fear and the emotion vector"despair" by combining fear and sadness.

V. Detection of depression and results

A. Detection of depression

We have already generated our data base of emotion, as explained before. It consisting of emotion vectors classified into 2 categories: negative and positive emotions. Negative emotions are, for example: grief, sadness, despair, hate, anger etc. Positive emotions are, for example: joy, romantic love, platonic love, reverence etc. Our method consists on detecting and classifying all the emotions felt throughout the day and give a global report. However, to analyze a given vector and determine the nearest emotion from the known ones we need a tool to calculate the similitude from the vector and the known emotions. For this, we propose to use the Euclidean distance (2-norm distance). Therefore, we have to compute for a given vector V1 the Euclidean distance between it and all the vectors of the data base. Then, we keep the vector of the data base minimizing the Euclidean distance. This vector represents the nearest emotion of V1 and the computed distance gives an idea of the precision of this interpretation. For example, we can found that the nearest emotion for the vector V1 is "despair" with a distance equals to zeros. We can affirm without doubts that V1 represents the emotion "despair". More the distance from the nearest vector is important, less the interpretation is accurate. So, the proposed method, using the Euclidean distance, permits to analyze automatically a given vector and provides the best interpretation of this vector.

Algorithm 1 Detection of depression

```
int negative_day = 0
while negative_day¡14 do
  while True do
    Wait_for_new_day();
    E_d= Emotion_Detection(); //gives all the emotions felt throughout the day
    boolean day_is_negative=positive_or_negative(E_d);
    //gives true if the new day is a negative day
    if day_is_negative then
      negative_day++;
    else
      negative_day = 0;
    end if
  end while
end while
send_alert();.
```

As previously stated, to detect depression we focus mainly on negative emotions. Therefore, we propose a method to classify all the emotions felt throughout the day and give a health check. For example, a day with more negative than positives emotions felt is considered as a negative day. In fact, according to [7] [22], a person who experiences negatives emotions for longer than a two-week period, may be diagnosed with major depressive disorder. Thus, the proposed algorithm calculates the number of successive negative days in order to prevent depression. If the number of successive negative days is greater than 14 (two weeks), our system conclude that the person could be suffering from depression and sends an alert message to the doctor (see algorithm 1).

B. Results

As shown in Figure 5.1, the analysis of the EMG signal using the proposed method, gives high accuracy percentage of detection of negative emotions. Indeed, we obtained for example 92% for anger and 62% for hate and 58% for grief. Figure 5.2 shows the results of accuracy obtained using the respiration (RESP) signal. Our method recognized anger with more than 73%, hate with 66.66% and grief with 50.58%. As know, it is hard to recognize emotions very accurately only with one modality. For this reason, we plan, for the future work, to conduct studies on multimodal recognition. Indeed, by applying two modalities, results could be improved up to 82%. Figure 6 gives an example of report generated after applying the algorithm of detecting depression along a period of 25 days. In the first scenario,

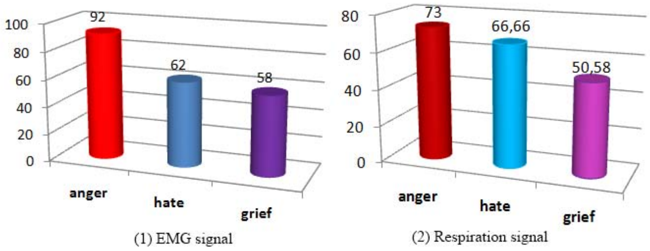

Figure 5. The classification rates of the proposed method using EMG and RESPIRATION signal

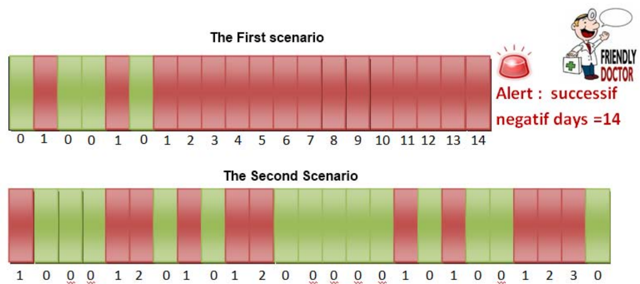

Figure 6. Depression detection

our algorithm calculate the number of successive negative days and conclude that the person could be suffering from depression and sends an alert message to the doctor. However, in the second scenario, our algorithm conclude that the person have a normal mood state.

VI. CONCLUSION AND FUTURE WORK

In this paper, we have presented a new approach for prevention and early detection of depression using physiological sensors. it consists of two main steps: the capture of physiological features and analysis of emotional information. The first step permits to detect emotions felt throughout the day. The second step consists on analyzing these emotional information to prevent depression. For emotion detection, we used signal processing algorithms to extract features and the the K-Nearest Neighbor algorithm to classify the emotion. Experiments show the efficiency of the proposed method in detecting negative emotion by giving high recognition rate. Finally, our system evaluate emotional information in order to detect depression and send an alert to the doctor. For the future work, we would extend our method to take into account others information such as voice communications, daily patterns of sleeping, eating, social interactions and online behaviors to improve prevention of depression.

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Time and Frequency Domain Measures of Heart Rate Variability in Schizophrenia

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Abstract — It has been reported that schizophrenia patients have altered cardiac autonomic regulation and changed heart rate variability. The goal of this study was to analyze whether schizophrenia patients may exhibit distinctive Heart rate variability time and frequency domain parameters for control subjects compared both at rest and during auditory stimulation periods. Photoplethysmographic signals of thirteen schizophrenic patients and thirteen healthy subjects were used in the analysis of heart rate variability. Results show that heart rate in patients was higher than that of control subjects indicating autonomic dysfunction throughout the entire experiment. In comparison with control subjects, patients with schizophrenia exhibited lower high frequency power and a greater low-frequency to high-frequency ratio. Moreover, while alerting stimulus decreased parasympathetic activity in healthy subjects, no significant changes in heart rate and frequency-domain HRV parameters were observed between the auditory stimulation and rest periods in schizophrenia patients.

Keywords*-schizophrenia; heart rate variability; photoplethysmography; time and frequency domain measures.*

I. INTRODUCTION

Schizophrenia is a mental disorder characterized by some positive symptoms such as hallucinations, delusions and negative symptoms such as loss of motivation, lack of interest, disturbances in cognitions and emotions [1, 2]. According to the theories about symptom development in schizophrenia, it is claimed that indication of psychosis is related to autonomic dysfunction [3]. Therefore, there have been numerous studies that analyze disturbances of autonomic activity in schizophrenia patients [4-6].

Heart rate variability (HRV), which describes the variation in heartbeat intervals, is an important measure for investigation of the autonomic nervous system (ANS) activity. HRV analysis has been widely used to assess ANS activity in myocardial infarction, diabetic neuropathy, cardiac transplantation, myocardial dysfunction, tetraplegia [7], diabetes mellitus and renal failure [8]. Moreover, HRV analysis has been widely used in schizophrenia patients due to the relationship between symptoms of the disorder and cardiac autonomic irregularities [3, 9-12]. Results for altered cardiac autonomic regulation and changed HRV in schizophrenia patients are reported. It has been found that they have higher rates of cardiac disease and morbidity due to the dysregulation of ANS activity.

Most of these studies in schizophrenia patients are restricted to electrocardiogram (ECG) based HRV signal analysis. However, there are some of the problems of this technique such as drift, electromagnetic and biologic interference, the number of wires, and the complex morphology of the ECG [13]. On the other hand, photoplethysmogaphy (PPG) is reported as a simpler and easier process than analyzing HRV parameters from ECG data according to the results of a previous study [14]. In previous studies, HRV signal is usually analyzed in the time and frequency domain. While time domain measures of HRV have been used to evaluate the interbeat interval (IBI) variability, spectral analysis of sequences of IBIs can be used to assess the distribution of power across different frequency bands and reflects the sympathovagal balance between the sympathetic and parasympathetic activity.

The aim of the present study is to identify the differences in PPG based HRV measures during alertive acoustic white noise (WN), sedative Classical Turkish Music (CTM), and restive (no stimulation) periods for schizophrenia patients and healthy control subjects. While Section II is related to data acquisition and analysis techniques, Section III, IV and V are about results, discussion and conclusion of the study, respectively.

II. METHODS

A. *Subjects*

Thirteen schizophrenia patients diagnosed by the DSM-IV (Diagnostic and Statistical Manual, Fourth Edition) [15] and thirteen healthy subjects, approximately matched in age and gender, participated in the study. Table I lists the demographic and clinical data of the participants. None of the subjects had history of diabetes mellitus, hypertension, respiratory diseases, cardiovascular diseases, hearing difficulties and co-morbidity in terms of psychiatric problems. Both the university and hospital ethics committee approved the protocol, and a written informed consent was obtained from all participants before the study was conducted.

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TABLE I. DEMOGRAPHIC AND CLINICAL DATA OF THE PARTICIPANTS

	Participants	
	Controls	***Patients***
Number	13	13
Male/Female	8/5	7/6
Age (years ± std. deviation)	33.95 ± 8.33	33.39 ± 6.86
Age of onset in male/female	-	20.82 ± 5.21 / 20.08 ± 6.37
Medication status (drug-naïve/drug-free)	-	13/0

B. *Data Acquisition*

The study was carried out whilst participants seated in a quiet, temperature controlled and illuminated room without moving in Bakırköy Mental and Nervous Diseases Training and Research Hospital. The PPG data were recorded using Biopac MP150WSW data acquisition unit, PPG100C amplifier, TSD200 transducer and associated Acknowledge Software, which is an interactive program that measure, analyze and transform data.

The transducer was strapped on to the middle finger of the non-dominant hand of the participant and connected to the amplifier. A baseline data recording was obtained prior to the experiment. Data were recorded for 2 min. resting state (resting 1, R1) before auditory stimuli exposure, then following 2 min. period of WN exposure, following 2 min. period of music exposure and a 2 min. post-exposure resting (resting 2, R2) period and were digitized at a sampling rate of 250 Hz. The subjects listened to stimuli binaurally through headphones with the intensity of 75 dB.

WN is a kind of sound of rain on a river and was selected because of its uncomfortable, annoying evaluation from previous studies [16, 17]. On the other hand, CTM was selected as a sedative music period [18]. According to the Turkish philosopher Farabi, the effect of this kind of music induces serenity and ease [19].

C. *Heart Rate Variability Analysis*

Matlab 7.6® software package was used for data analysis. The PPG data were first low-pass filtered using a Butterworth filter (8^{th} order, cut-off 8 Hz). A detection algorithm, which finds min and max points of waveform, was implemented to detect peaks of the PPG signal and tachograms were plotted. Then, an interpolation with a sampling rate of 4 Hz was applied and data were detrended using a least-squares polynomial fitting detrending technique, which is explained in our previous study [18, 20].

In the time domain analysis of HRV, the mean length of all PP intervals (PPint) and the heart rate (HR) in each measurement period (2 min.) were computed. In the frequency domain analysis, spectral analysis was performed using the Welch's algorithm, which is an averaging modified periodogram to estimate the power spectrum [21]. The power spectrum of the HRV signal was divided into three bands: very low frequency-VLF (0-0.04 Hz), low frequency-LF (0.04-0.15 Hz) and high frequency-HF (0.15-0.5 Hz). The power spectral density of the LF and the HF band were computed by integration of the power spectrum over the related frequency range (square milliseconds-ms2) in each period. While the LF band reflects sympathetic activity, the HF band is related to parasympathetic activity. The ratio of LF to HF power (LF/HF) was calculated to assess the sympathovagal balance for indicating the function of the ANS activity.

D. *Statistical Analysis*

All statistical analyses were performed using the SPSS (version 20.0) statistical software package. Comparisons of HRV features between the patients and controls in each period were executed using an independent sample Student's t-test. Under the null hypothesis, defined as "no difference in the HRV features of patients and controls", the data follows a normal distribution. To compare the differences in HRV between sequential periods, paired sample Student's t-tests were performed on both groups, separately. The student's t-test was chosen based on a finding from Levene's test. Due to confidence level of 95 %, results were considered as significant at the level of $p<0.05$.

III. RESULTS

In this study, PPG signals were recorded during varying measurement periods, in which time and frequency domain measures of HRV were computed for the PPint of healthy control subjects and schizophrenia patients. In Table II, the differences in HRV measures observed between schizophrenia patients and control subjects are summarized.

A. *Comparisons of HRV measures between groups*

Time domain measures of HRV for patients and control subjects during measurement periods are shown in Fig. 1.

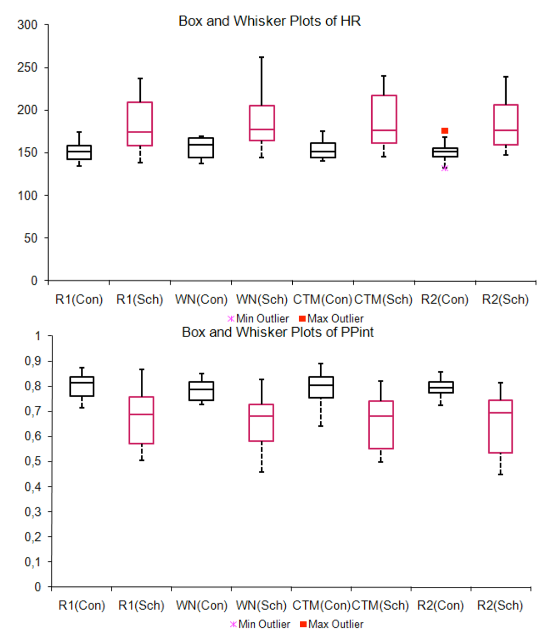

Figure 1. Box and Whisker plot comparison of HR and PPint between schizophrenia and control groups during different experimental periods.

TABLE II. TIME AND FREQUENCY DOMAIN HEART RATE VARIABILITY MEASURES.

	Controls				*Patients*			
	R1	***WN***	***CTM***	***R2***	***R1***	***WN***	***CTM***	***R2***
Mean HR	151.6 (11.7)	156.5 (10.8)	153.3 (10.3)	151.3 (10.1)	181.8 (34.0)	187.7 (36.7)	185.7 (32.6)	183.2 (30.7)
Mean PP interval	0.7978 (0.053)	0.7860 (0.044)	0.7879 (0.074)	0.7944 (0.036)	0.6799 (0.123)	0.6602 (0.117)	0.6636 (0.112)	0.6586 (0.134)
LF pow. (ms2)	41.6 (3.13)	50.9 (2.68)	47.6 (3.62)	43.1 (3.73)	42.7 (3.81)	49.4 (3.11)	47.1 (3.54)	45.4 (3.77)
HF pow. (ms2)	33.3 (3.36)	29.8 (2.34)	32.8 (2.79)	33.2 (2.61)	27.2 (3.32)	24.7 (2.12)	25.2 (3.25)	26.5 (3.27)
LF/HF	1.26±0.14	1.72±0.15	1.46±0.18	1.31±0.14	1.58±0.16	2.01±0.23	1.90±0.31	1.74±0.27

The schizophrenia patients showed a significantly higher HR than control subjects during all periods of the procedure ($p<0.05$). However, healthy subjects exhibited a high degree of HRV, which is described by the variation in mean PPint ($p<0.05$).

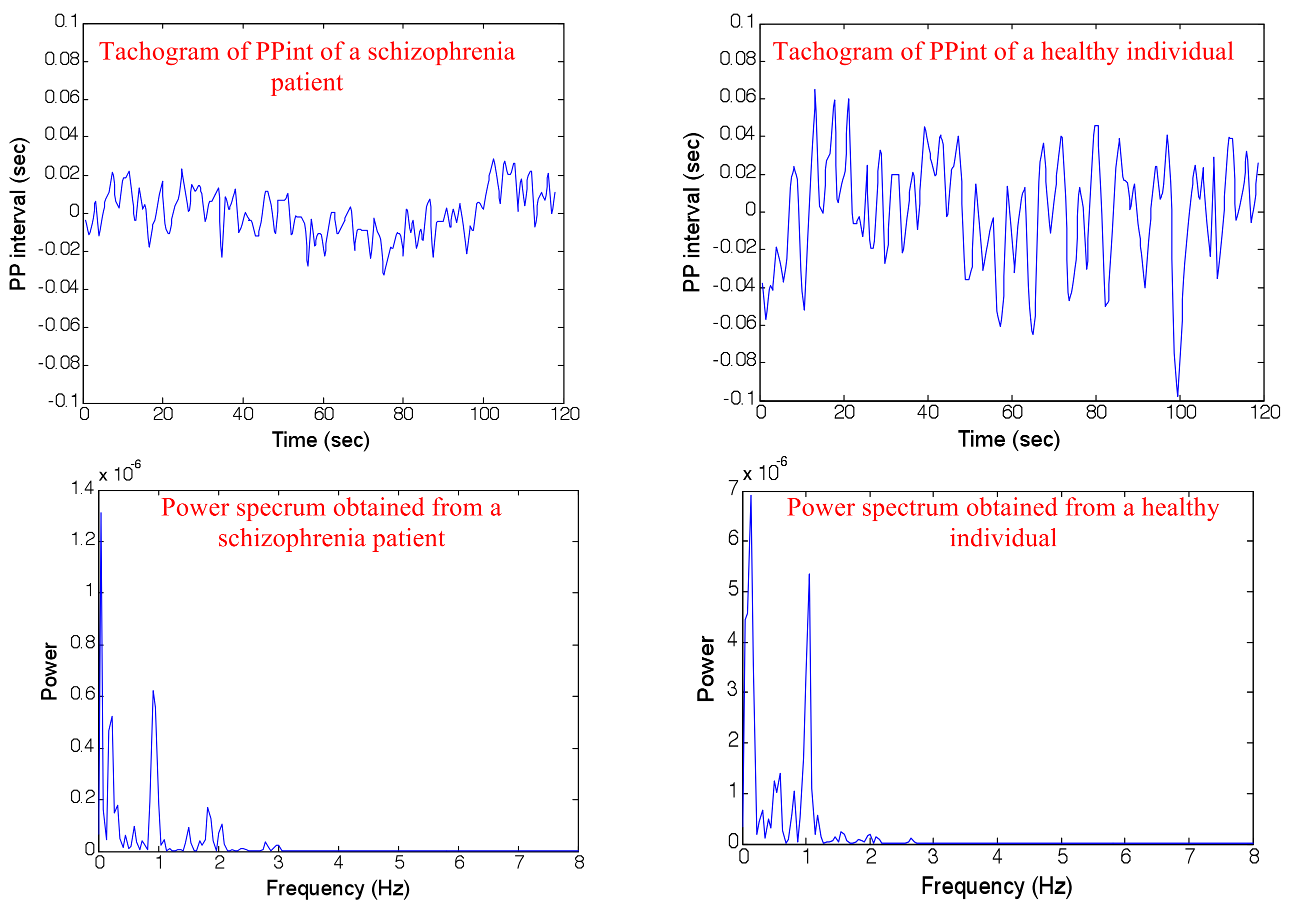

Figure 2. Spectral analysis of HRV in restive condition in a healthy subject and schizophrenia patient. Top: Interbeat interval tachogram of a schizophrenia patient (left) and a healthy individual (right). Bottom: Corresponding power spectrum obtained from the patient (left) and control subject (right)

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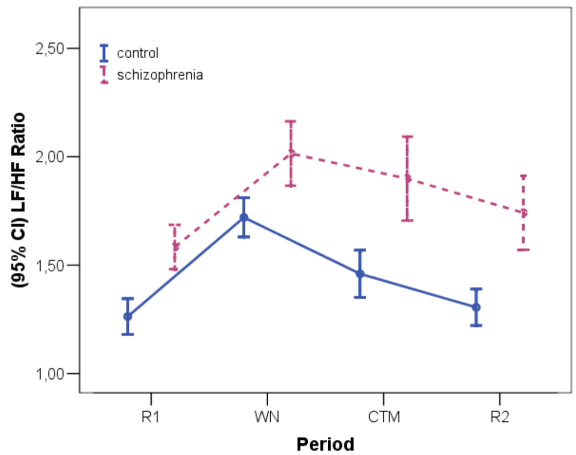

Figure 3. Comparison of the changes in the LF/HF of HRV between patients with schizophrenia and healthy subjects

The baseline tachograms (top panels) and their corresponding power spectra (bottom panels) of a patient in the schizophrenia group (left) and an individual in the control group (right) are shown in Fig. 2. From here, it may be seen that, the individual with schizophrenia exhibited a higher HR, shorter PPint, and decreased HRV during the restive baseline period as compared to the healthy subject. The PPint feature of the schizophrenia patients during the whole procedure was significantly lower than that of the control subjects ($p<0.05$). While the LF power in schizophrenia patients was not different from that in control subjects, the HF power was significantly reduced in the patients ($p<0.05$) during all periods of the procedure. Moreover, schizophrenia patients showed increased LF/HF ratio as compared to control subjects during both stimulation and restive periods (Fig. 3).

B. *Comparisons of HRV measures within groups*

Auditory stimulation caused an increase in HR in both groups as compared to that during restive periods. While the control group showed the greatest HR during the WN exposure, no significant HR change was reported during the WN period and CTM period in schizophrenia patients. Although HR decreased during CTM as compared to the WN period, this difference did not reach significant levels in either the control ($p=0.1$) subjects or schizophrenic patients ($p=0.18$). The decrease in HR continued in the R2 period for both the control subject and patient groups. However, for both groups, no significant change was reported over the CTM and R2 periods. The results indicate that there was an insignificant decrease in PPint between restive periods (R1 and R2) and stimulation periods (WN and CTM) in both groups.

Auditory stimulation evoked an increase of LF power and LF/HF ratio from the baseline and a decrease of HF power in the HRV in both groups ($p<0.05$). While the LF power increased more during WN than during CTM, the WN evoked a more deceleration of HF power from the baseline as compared to CTM in the control group. The LF/HF ratio of healthy subjects was higher during WN than during CTM. In contrast, there were no significant differences in terms of LF, HF, and LF/HF ratio when the different auditory stimuli were heard by the group of schizophrenia patients. The restive period (R2) after stimulation periods caused a significant decrease in LF power in healthy individuals, whereas LF power did not change significantly during the R2 period in the schizophrenia group.

IV. DISCUSSION

It has been reported that altered autonomic function is associated with higher rates of cardiac disease and morbidity in schizophrenia patients [22]. Therefore, HRV analysis has become a powerful and useful tool in clinical research to assess ANS activities in schizophrenia patients. By combining the knowledge about impairment in auditory stimuli discrimination with altered autonomic regulation of schizophrenia patients, we aimed to investigate the PPG based HRV parameters during different types of auditory stimuli in patients. It was found that schizophrenia patients had higher HR and shorter PPint than control subjects during all periods of the procedure. This may be observed as a result of disorder-related autonomic nervous system changes [3]. Schizophrenia group also exhibited a similar LF power, a significant decrease in HF power and an increase in the LF/HF ratio as compared to healthy subjects during all the periods of the procedure.

Although HR increased during auditory stimulation periods in both groups, changes between the two stimulus periods were not significant for schizophrenia patients. The LF power and the LF/HF ratio increased during stimulation periods as compared to restive periods in both schizophrenia and control groups. However, the LF power was higher during WN exposure than during sedative CTM exposure in the control group. On the other hand, HF power was higher during CTM than WN, but remained the same in both restive and CTM periods. Namely, while alerting stimulus increased sympathetic activity more, it caused a reduction in parasympathetic activity in healthy subjects. Therefore, the LF/HF ratio was highest during WN in the control group. This confirms the result of a past study that states the HF power, which is decreased by uncomfortable stimuli, may be sensitive to stress reduction in resting state [23]. In contrast, there were no significant differences in terms of LF, HF, and LF/HF ratio in schizophrenia patients during these two different auditory stimuli periods. This may be related to impairments of schizophrenia patients in auditory discrimination [24] or related to cardiac autonomic dysfunction in schizophrenia patients.

A post hoc power analysis revealed that on the basis of the mean a limited statistical power because of the modest sample size. Therefore, it is suggested to increase the number of participants in each group for future studies.

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V. CONCLUSION

In conclusion, the results obtained for HRV measures support that the variations in cardiac autonomic activity during the restive baseline and other stimulation periods are different between schizophrenia patients and healthy individuals. The reduced parasympathetic activity in schizophrenic patients can be considered as strongly relating the risk factor of cardiac morbidity.

ACKNOWLEDGMENT

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Accurate and Reliable Recommender System for Chronic Disease Diagnosis

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***Abstract*-With the rapid growth of chronic disease cases around the world, healthcare support systems like recommender systems play a major role in controlling the disease, through providing accurate and trustworthy disease risk diagnosis prediction and acknowledgement of disease risk status, that assists healthcare providers to have 24/7 remote patient monitoring system and assist patients to have 24 hour access to the medical care. Providing an accurate real-time recommendation for medical data is a challenge according to its complexity represented by unbalance, large, noisy and/or missing data. The Chronic Disease Diagnosis (CDD) recommender system expectation is to give a high accuracy and reliable disease risk prediction. This paper presents a CDD recommender system model using multiple decision tree classification algorithms. Decision tree algorithms are applied to achieve high accuracy disease risk predictive model. Historical patients' medical data from the Middle East is used to train the model. Determining the relevant features through Attribute Selection method is used to reduce data generation and improve the predictive model performance. Merging patients' lab and home test readings is considered to leverage the diagnosis fidelity. Diabetes diagnosis case study is designed through this research as experiment to show the feasibility of our model.**

Keyword-E-Health; Remote Chronic Disease Diagnosis prediction; Diabetes healthcare management system; Decision Tree; Random Forest.

I. INTRODUCTION

In recent years, a pattern of chronic diseases has started to emerge in the Middle East similar to the rest of the world [1]. These diseases appear in the form of increases in obesity, heart diseases, and diabetes (both types 1 and 2). This growth in chronic illnesses along with the increase of inactive lifestyle in the Middle East has imposed great pressure on healthcare providers, especially when trying to ensure a structured patient follow-up to be achieved after each therapeutic change.

The rapid increase in ICT (Information and Communications Technology) development has opened a new era for researchers to develop a number of E-Health applications that are starting to play a major role in improving healthcare services. Recommender systems [2] have been emerged and being increasingly used by many applications, like E-Commerce and E-Health [3] according to their feasibility in automatically extracting useful information and predicting and recommending appropriate results to consumers. Therefore, this research applies a recommender system to manage the chronic disease, which minimizes both the risk of such a disease as well as the cost that is associated with it.

The most popular technique of recommender systems is collaborative filtering, which utilizes users' experiences or histories to generate predictions of the unknown preferences [4]. For example, in a system recommending books there usually are two sets, a set of users *U* (e.g., the readers) and a set of items *I* (e.g., the books), and a utility function r between the two sets (e.g., the books rating by users). In its most common formulation, the recommendation problem is reduced to the problem of estimating ratings for the items that have not been seen by a user, selecting for each user $u \in U$, the item $i \in I$ that maximizes the defined user's utility.

In our case the set of users, *U* represents patients, while the set of items *I* is the patients' medical record attributes represented by disease risk factors and diagnosis. The relationship between the two sets, instead of being a user preference rating, is the risk factors readings and an ordinal set of rating the disease risk diagnosis (represented by 0-10 scale). This rating is determined by physicians based on various factors such as patient's vital signs and lab tests.

The hypothesis is that, if a patient's chronic disease risk is predicted with high accuracy, we will expect the improvement of patients' health conditions, lifestyle adjustments along with reducing the healthcare services costs.

A. The Research Problem

Accuracy is the essential factor of recommender systems [5]. In our research, accuracy reflects how the recommendation is valuable and correspondent with the patient's physiologic state and complexity of disease in order to be valuable to the users who are looking for trusty recommendation. To achieve that, recommender systems should minimize false positive and false negative errors. For example, a specific disease risk diagnosis is not useful for a patient (false), which is recommended by the system (positive). While a specific diagnosis is useful for a patient (false), but it is not recommended (negative).

Our purpose of developing the recommender system for CDD is to provide efficient recommendations benefit users remotely. To improve the accuracy of recommendations for CDD; we consider: the nature and complexity of medical data such as different types of data, large number of parameter, and missing and noisy data.

For this consideration, as known, the patients' states of health and disease risk are monitored through symptoms,

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vital signs, laboratory test results, etc. Those results and readings are generated by different sources like different data entry-medical workers, medical home sensors, etc., which are not corresponding in structure or quality. Thus, medical data can have features of different types and may contain various types of errors (missing data and noisy data) that occur for a variety of reasons for example: erroneous attribute values during the insertion process, values cannot be recorded when the data is collected, a doctor may not order all applicable tests while diagnosing a patient [6], and some personal data is ignored by users because of privacy concerns. Dealing with such data is a challenge to get accurate and reliable recommendations as it can have a significant effect on the recommendations quality and accuracy.

Our contribution is to provide more accuracy and reliable recommendations in order to assist patients controlling their chronic disease and assist healthcare providers to have 24/7 remote patient monitoring system.

B. Decision Tree Classification Approach

In this work, the decision tree classification approach [7] has been adopted within a recommender system to improve the prediction accuracy. Decision tree is a very popular data mining method for classification and regression, where decision tree Collaborative Filtering models act as classifier to classify tasks [8].

Different decision tree classification models such as J48[9], Decision Stump[10], REP Tree[11] and Random Forest [12] have been constructed to predict the chronic disease risk. RF model has proven its feasibility in providing accurate predictions over the medical data, while the other decision tree classification models have been used for prediction performance comparisons.

C. Random Forest

RF algorithm [13, 14] was developed by Brieman in 2001. RF is an ensemble classifier that consists of many decision trees created by using bootstrap samples of the training data and random feature selection at each node to grow each tree; it outputs the class that is the mode of the class's output by individual trees. In this way, an RF ensemble classifier performs better than a single tree from classification performance point of view [12]. And as each node is split using the best among a subset of predictors randomly chosen at that node, RF performs very well compared with many other classifiers and is robust against over-fitting. Furthermore, RF can be used to estimate missing values [15]. Generally, RF is a powerful statistical classifier that has some advantages compared to other statistical classifiers; see [16] for RF advantages.

The remaining of the paper is structured as related work in section two. CDD recommender system is in section three, followed by CDD scenario and methodology. Diabetes diagnosis experiments, outcomes, and results are demonstrated and discussed in section five. Conclusion and future work are presented in section six.

II. RELATED WORK

This section demonstrates the current researches in the area of recommender system and its uses with healthcare applications, and the RF method used in disease diagnosis field. Recommender systems have been used by many researchers in different areas such as: movies, healthcare, E-commerce, etc. [17]. With focus on healthcare applications, Davis *et al.* [18] proposed a Collaborative Assessment and Recommendation Engine (CARE), which relies on patient's medical history using only ICD-9-CM codes without considering other information such as lab tests, etc. CARE predicted each patient's future disease risks based on their own medical history and that of similar patients using ICD-9-CM codes. The experimental results demonstrated that CARE performed well at capturing the future diseases and facilitating discussion about early testing and prevention. Sapon *et al*. [19] used supervised learning algorithms of Artificial Neural Network for diabetes prediction. The network was trained using the data of 250 diabetes patients. Scaled Conjugate Gradient algorithm with value of R=0.88026, produced the best performance in the prediction of diabetes compared to the other algorithms.

Accuracy of the recommender system is vital in many applications. Therefore, different Collaborative Filtering (CF) recommendation approaches have been used to improve the reliability, performance and accuracy of the recommender system. Noh *et al*. [20] used multiple imputation-based CF approach for recommendation system to improve the accuracy in prediction performance by solving the incomplete data problem of CF algorithm. The approach replaces each missing value with m>1 acceptable values from their predictive distribution and converts an incomplete dataset into m complete dataset and each dataset is used for analysis. Overall estimate is then obtained by combing these m estimates. The prediction power was improved by adopting CF algorithm on the complete dataset after imputation is made.

The RF is one of the decision tree classification methods that prove its feasibility to be used with healthcare applications. Özçift [12] presented a resampling strategy based RF ensemble classifier to improve diagnosis of cardiac arrhythmia. The resultant accuracy of the classifier was found to be 90.0%, and the results of experiments demonstrated the efficiency of random sampling strategy in training RF ensemble classification algorithm. Ko *et al*. [21] used RF to demonstrating an efficient white blood cell (WBC) image classification method. WBC was classified into five different categories that are necessary for accurate disease diagnosis. The experimental results showed that using the random forest with dynamic features could indeed improve the classification performance.

As demonstrated by the above surveys, recommender systems prove their usability in predicting and recommending the appropriate results to consumers. In this paper, our challenges are to provide a real-time and quality recommendation for a large, missing and lab tests merged with home tests medical data.

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As such, because of the power and efficiency of the RF classification technique [16], it has been implemented in the development of a recommendation system for CDD. Such a system is presented as a case study for the model developed in this work.

III. Chronic Disease Diagnosis Recommender System

CDD recommender system is represented by prediction and recommendation. It depends on a set of patients' health history to train and build a model that is able to predict and recommend disease risk and disease risk status for the future cases. Those predictions and recommendations are approved by physicians. As shown in Fig. 1, the CDD recommender system requires input information to produce recommendation and predicted items. In this work, diabetes is used as a case study.

The input information that is needed to build up the predictive model of CDD for diabetes and make prediction for undiagnosed patients is categorized into:

Training data: a bulk of historical medical records of previous diabetic patients (935 records) has been collected from hospitals in Oman. The collected data records are represented by a number of attributes, values and doctors' assessment (diagnosis) for each case. Oman Health Authority based on international standards defines these factors. All of these records have been tested and diagnosed by doctors in Oman hospitals. A scale from 1 to 10 has been used for the diagnosis to give more opportunities for better classification. The doctor diagnosis scale is based on: 1–2 represents excellent, 3–4 good, 5–6 fair but needs control, 7–8 bad with bad control, and 9–10 represents a critical condition. Fig. 2 demonstrates a sample of the collected data.

Demographic data of active patient: refers to the user's profile such as: name, age, level of education, type of end user device and type of connectivity.

Medical dataset of active patient: formed by two types of data. The first type is known as home-tests such as blood sugar level, blood pressure, and weight. The other type involves results obtained in the laboratory, which is usually carried out over a long time interval, depending on the condition of the patient. Fig. 3 shows sample of the diabetes medical dataset of an undiagnosed patient case.

The output of the system is:

Prediction and recommendation: prediction is expressed as a numerical value that represents the disease risk diagnosis of an active patient and to the future cases. This prediction value should be within the same scale as the diagnosis values provided in the training dataset. Recommendation is expressed as disease risk status acknowledgment, which the active patient is seeking for.

IV. CDD Recommender System Scenario

The scenario consists of number of major activities, which starts by building the predictive model of recommender system, as shown in Fig. 4 and illustrated in the following sections. Multiple decision tree algorithms are adopted to achieve a high accurate predictive model.

A. *Building the Predictive Model*

The predictive model is built as follows:

1) *Data Preprocessing*

Filtering the data might be necessarily accomplished to avoid the creation of ambiguous or inappropriate models and improve the learning model performance [22]. In our system, the diabetes dataset is filtered by determining the relevant features through InfoGainAttributeEval Attribute Selection method, furthermore, the data is also transformed to a form appropriate the classification. InfoGainAttributeEval has ranked the relevant and significance features sequentially as follows: LDLC, Cholesterol, Triglyceride, FBS, HBA1C, BMI, HDLC, DBP, Age, SBP and Sex. As seen, the result shows that LDLC attribute, Low Density Lipoprotein Cholesterol, has a significant and highest effect on the diabetes diagnosis. The scale of diagnose is increased in conjunction with the increase of LDLC level. The patients with worse condition of diabetes (class diagnose 10) exhibit the highest readings of LDLC and vice versa.

2) *RF Algorithm*

The RF algorithm is utilized to analyze and segment the patients' records in training data into distinguished and related groups of classes based on the seen diagnosis scales. These classes are used to generate a predictive model that is able to predict the class of diagnosis of an active patient.

The workflow of RF algorithm starts by classifying the training datasets that is provided by the healthcare provider. *Kth* tree is constructed by sampling with replacement. At each node, *mth* variables are selected at random out of the total number of variables *M*, and the split is the best split on these *mth* variables. About one-third of the cases are left out of the bootstrap sample and not used in the construction of the *kth* tree. The out-of-bag data (oob) or bagging [23] is used to get an unbiased estimate of the classification error as trees are added to the forest.

It is also used to enhance accuracy through using random features and to get estimates of variable importance [14]. After each tree is built, each case left out in the construction of the *kth* tree is put down the *kth* tree to get a classification. In this way, a test set classification is obtained for each case in about one-third of the trees. At the end of the run, take *j* to be the class that received the most votes every time case *n*

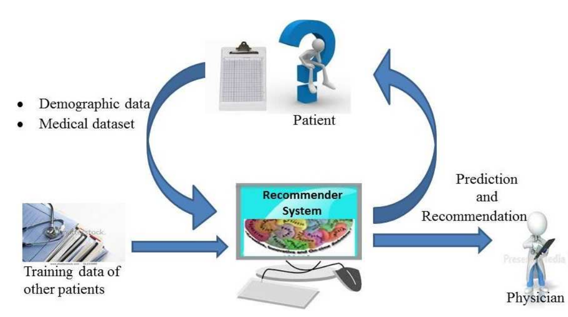

Figure 1: CDD Recommender System

PatientID	Age	Sex	BMI	SBP	DBP	FBS	HBA1C	Cholesterol	Triglyceride	HDLC	LDLC	(Class Lab Diagnosi
99901	40	2	23.2	130	80	186	6.6	206	92	51	136	6
99902	44	1	27.3	150	80	155	6.5	159	110	71	132	5
99903	51	2	22.1	140	80	188	5.5	169	84	55	98	5
99904	58	1	16.6	130	90	190	15.7	183	150	44	183	7
99905	38	2	28.7	130	90	144	10.7	228	111	58	148	7
99906	38	2	28.7	130	90	127	9.1	228	111	58	148	6
99907	45	2	26.3	184	108	142	6.2	221	124	55	142	7
99908	48	1	24	140	80	416	6.8	129	168	37	159	8
99909	54	1	19.5	160	110	151	15.3	171	146	29	113	7
99910	64	1	23	130	90	396	19	314	147	41	242	10

Figure 2: “10” sample records of total “935” diabetes training dataset

PatientID	Age	Sex	BMI	SBP	DBP	FBS	HBA1C	Cholesterol	Triglyceride	HDLC	LDLC	(Class label) Diagnosis
31477	69	1	26.4	120	70	166	7.4	158	119	39	97	?

Figure 3: Sample dataset of an undiagnosed active patient

was out of bag. In this case, the class of diagnosis is predicted by aggregating the predictions of the *kth* trees (the majority votes).

B. *New Data of Active Patient*

As shown in Fig. 4, the healthcare provider initiates a request to the request repository for collecting the home medical tests readings of an active patient. The request is sent to the patient-home medical sensor to collect those readings of the patient such as: blood sugar level, blood pressure, weight, etc. At the same time of sending the request, the healthcare provider provides the laboratory tests readings of the same patient (patient medical record). Those lab readings are merged with the home readings as a complete dataset in the profile of active patient (as shown in Fig. 3). This complete dataset has the same attributes of the training dataset, but the class diagnosis variable has no value and it is unknown.

C. *Prediction*

The complete dataset of an active patient is uploaded to the generated RF predictive model to predict the class of diagnosis and disease condition of patient. The dataset is analyzed and run over the tree model to finding the similarities between the current patient’s dataset and the training dataset from other patients [24].

D. *Alert Message*

Once the diagnosis scale is produced, it is sent to healthcare providers. Healthcare providers would examine the accuracy of the prediction and approve/correct them. The patient profile is then updated by adding the approved diagnosis to the medical record of patient. Finally, an assessment and acknowledgement alert message of the predicted disease diagnosis and recommended disease risk status is sent to the patient, and the updated patient’s medical record is stored in the training dataset repository. The latter action is performed in order to add an extra element of data to the training dataset, which as a result, would help in improving the performance of CDD recommendations for future cases.

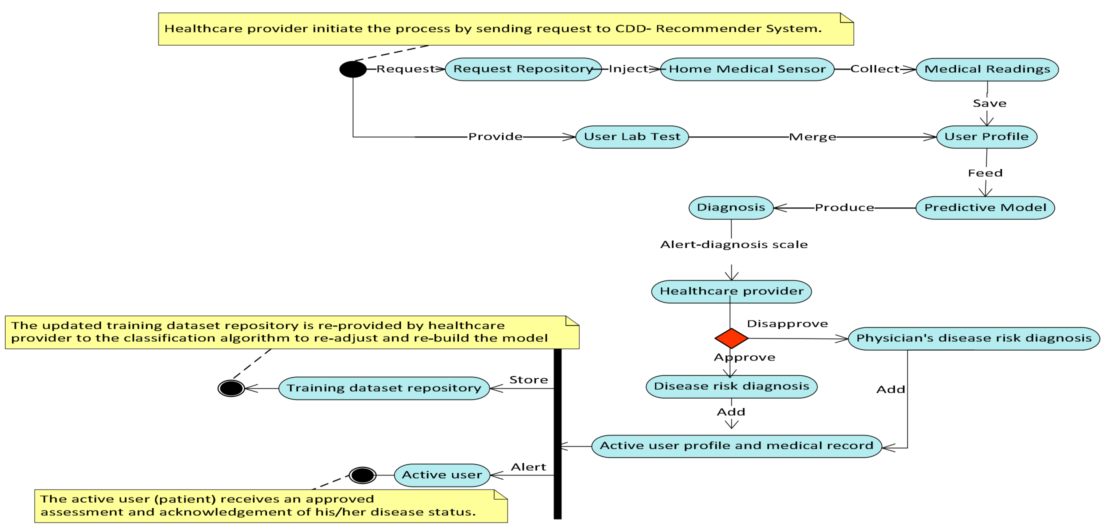

Figure 4: CDD Recommender System Scenario

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V. OUTCOMES

In this section, we present experimental results of the proposed predictive model and compare the prediction performance to other decision tree models like: J48, Decision Stump and REP Tree. The dataset used for this experiment is diabetes data set collected from hospitals in Oman. The collected data represented by 935 patients' records, "13" attributes including the doctors' diagnosis scale, and values of attributes for each case.

A. Metrics

Metrics such as MAE [7], Precision and Recall [15] are used to evaluate and compare the prediction performance of algorithms used. The accuracy of the system is high as the MAE of the prediction system is low. Precision and Recall should be maximized for well-performed prediction system.

The MAE is given by:

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}|f_i - y_i| = \frac{1}{n}\sum_{i=1}^{n}|e_i| \qquad (1)$$

where MAE is an average of the absolute errors $e_i = f_i - y_i$, f_i is the predicted class (diagnosis) and y_i is the actual class.

$$\text{Precision} = \frac{true\ positive}{true\ positive + false\ positive} \qquad (2)$$

$$\text{Recall} = \frac{\text{true positive}}{\text{true positive+false negetive}} \qquad (3)$$

B. Experimental results

Our experimental in building the predictive model for CDD recommender system using decision tree algorithms, has shown the following:

- RF has been built of 10 trees. Out of bag estimated error is 0.2877.
- RF has demonstrated 99.7% of correctly classified cases.
- Since we do not have a large dataset, we conducted a 10-fold cross validation [25]. Cross validation has been used with: J48, Decision Stump, and REP Tree algorithms. However, RF does not need cross validation method [14] because the test set error is estimated internally during the run.
- RF improves the accuracy by handling the missing data internally through the training and testing phase. In our case study, the dataset is complete. However, we randomly put missing values along the training data, and re-build the model with the aforementioned algorithms. The results show that our RF model still outperformed all other models.

The comparison results of predictions performance for different models show:

The model built using RF has less MAE and high Precision and Recall results compared with the other models results (as shown in Fig. 5). That shows the high quality and performance of our recommendation system for CDD built based on RF.

C. Evaluation and Results

To test our system, evaluate the performance and determine the efficiency of the algorithm used, 20 random samples of real patients' medical records have been tested and applied on the RF learning model and the other trees models. The results show that the RF model outperformed all other models (as seen in Fig. 6).

VI. CONCLUSION AND FUTURE WORK

In this paper, we presented an effective and reliable recommender system approach for CDD using data mining technique. The main contributions of this study are summarized as follows:

- The utilized method is expected to generate effective disease risk prediction for chronic disease patients.
- An ensemble trees classification algorithm is adopted. It handles the shortcomings of the medical data and generates a robust learning model that is able to provide more accurate predictions for online users.
- An Attribute Selection method, that determines the relevant features of medical data, is applied.
- The laboratory and daily-home test data of chronic disease are merged to accomplish more accurate results.
- Reliable prediction and recommendation results approved by physicians are sent to patients as alert messages.

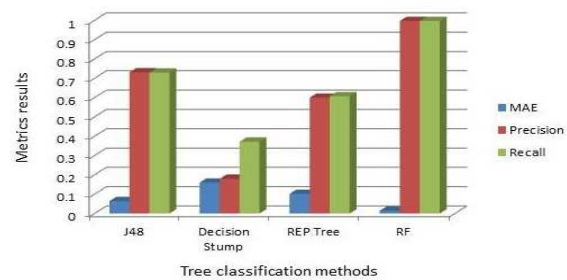

Figure 5: Metrics results of evaluating the prediction performance of J48, Decision Stump, REP Tree and RF

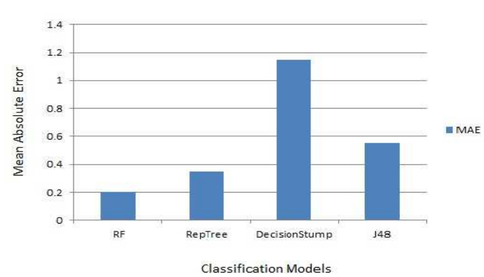

Figure 6: MAE values of four tree classification models tested on "20" samples of patients medical records

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Further study on testing different predication and recommendation methodologies will be considered to improve the system accuracy. In addition, more chronic disease case studies will be tested with the generated model. Moreover, the prediction result will be considered as one of the patient external features during our future work of extending the CDD recommender system. The extended work aims to provide medical advices and treatments recommendation along with the disease risk status.

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Extending the US Health Information National Trends Survey to China and Beyond: Promoting Global Access to Consumer Health Information Needs and Practices

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***Abstract*—The US-based Health Information National Trends Survey (HINTS) conducted every other year since 2003 by the National Cancer Institute (NCI) has become a major source for relevant data about the public's access to and use of relevant health information for cancer prevention and control. These data have been used to guide the development of evidence-based health communication intervention programs to reduce health information gaps and promote informed health decision making in the US. An innovative collaboration has been established between the NCI, George Mason University's Center for Health and Risk Communication, and Renmin University of China's Public Opinion Research Institute to conduct a biennial representative national HINTS survey in China, under the auspices of the Chinese Ministry of Health. Pilot data are currently be collected in two major Chinese cities, with full national administration of the first biennial HINTS-China research program to be conducted in 2013. Data gathered from the HINTS-China surveys will be used to guide evidence-based health promotion interventions across China to promote public health. This exciting international research program opens the door to expanding the HINTS research program to many other countries around the world to help promote global health.**

Keywords-health information; HINTS; National Cancer Institute; China; health communication.

I. INTRODUCTION

Access to and effective use of relevant, accurate, and timely health information is critically important for guiding the important health-related decisions that consumers and providers must make across the continuum of care to promote health and well-being [1]. This includes decisions about the prevention of health risks, health promotion behaviors, the detection and diagnosis of health problems, the treatment of health problems, and strategies for living with health threats (survivorship) [2]. The National Cancer Institute (NCI) introduced the Health Information National Trends Survey (HINTS) research program in 2003 to track the American public's access to and use of relevant health information, as well as their preferred ways to receive needed health information [3]. Data from the HINTS research program has helped health promotion leaders to identify serious public health information gaps and to guide targeted health education intervention programs to reduce

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these gaps for enhancing informed health decision making, especially concerning cancer prevention and control [4]. The HINTS survey has been conducted roughly every other year since 2003 by the NCI and has become a major source for relevant data about past, current, and evolving public access to and use of relevant health information [4, 5, 6]. The HINTS research program provides health promotion experts with critical information about both the most glaring public health information deficits that need to be addressed and the best ways to communicate needed health information to key audiences.

The lessons learned from the HINTS research program about access to health information in the US can be profitably extended to other nations and regions of the world to promote global health. Global health experts have learned that while there are often major differences in the ways health problems and solutions are expressed in different parts of the world, there are also many similarities in health threats and there is strong demand for cooperation in addressing these threats [7]. There have been calls to expand the HINTS research program to other parts of the globe [8]. In response to these calls, HINTS-China will be the first major expansion of the HINTS research program beyond the US (and its territories). HINTS-China is an active and innovative international collaboration between the NCI (in the US), the Chinese Ministry of Health, George Mason University's Center for Health and Risk Communication, and Renmin University of China's Public Opinion Research Institute. We are currently gathering pilot data in two major cities in China (Beijing and Hefei) during 2012 and early 2013 to refine Chinese language HINTS questions and delivery strategies, in preparation to be begin national administration of the first biennial HINTS survey in China in late 2013.

II. The Need for HINTS Research in China

This exciting new research program is especially relevant in China, where there are serious public health concerns about cancer prevention and control. Cancers are now the leading cause of death in urban China and the second leading cause of death in rural China [9, 10]. Current evidence suggests there is a serious and growing cancer burden in China, with increasing levels of cancer incidence, morbidity, and mortality [10, 11]. To reduce the cancer burden in China there is a concerted need to encourage cancer screening and early detection to promote timely cancer treatments, as well as to facilitate increased focus on cancer prevention activities [9, 12, 13]. Achieving these cancer prevention and control goals in China, as in other parts of the world, depends to a large extent on disseminating relevant and strategic health information about cancer prevention and control to key audiences to inform and motivate health decision making by health care consumers, providers, and policy makers [14]. The HINTS-China research program has the potential to establish the evidence-base for guiding strategic health communication programs for promoting cancer prevention and control in China.

The HINTS-China research program builds upon the NCI's well-established US national HINTS research program [3, 4, 5, 6]. The HINTS-China research program is adapting the latest HINTS questionnaire items, using similar core questions, adapted to the unique health issues and communication characteristics of the Chinese public. The focus of the HINTS-China survey will be on access to and use of cancer information.

III. Focus of the HINTS-China Research Program

The HINTS-China survey will recruit a large representative national sample in China across both urban and rural areas representing all of the major regions of the country. Special sections of the HINTS-China questionnaire will focus on relevant Chinese health issues, such as the link between smoking and lung cancer (the leading cause of death from cancer in China), immunization for hepatitis B, and screening for colorectal, breast, and cervical cancers [9]. We plan to adapt the NCI's comprehensive HINTS data dissemination program for providing information from the HINTS-China research program to health care researchers, consumers, providers, and policy makers.

Several of the unique features in the HINTS-China research program include the translation of the latest HINTS questionnaire into Chinese languages and adjusting the wording of the questions to adapt to unique Chinese respondent cultural issues. HINTS-China data will be collected through standardized personal interviews to ensure a good response rate and full collection of data. Sampling strategies will be employed to ensure a representative national sample of the Chinese public across all regions of the country, as well as both urban and rural areas of China. HINTS-China questions will examine the public's health information seeking practices, current levels of health information (including information deficits and misinformation), utilization and preference for different channels of communication, uses of health information acquired, and the source preferences of different segments of the Chinese public.

Current HINTS-China research activities include the translation and adaptation of the HINTS questionnaire for effective use with Chinese respondents. We are asking Chinese health professionals and policy makers to help us evaluate and refine the HINTS-China questions to make sure they are appropriate, understandable, and relevant for the Chinese public. We are pilot testing early versions of the HINTS-China questionnaire with diverse samples of respondents in Beijing and Hefei. Based upon these formative research activities we plan to carefully evaluate the HINTS-China pilot data, refine the HINTS-China research instruments, refine our administrative plan for collecting national HINTS-China data, develop plans for HINTS-China data analysis, data reports, results dissemination, and applications of the data for promoting public health, as well as to plan future biennial HINTS-China survey

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administrations. We will also be comparing the pilot data we collect with other surveys and research findings from studies conducted in the US, China, and other parts of the world. We expect the HINTS-China research program to build upon an expanding body of communication research being conducted in China and elsewhere about public access and use of health information.

IV. APPICATIONS OF THE HINTS-CHINA DATA

The HINTS-China research program will help provide the first comprehensive description of the current state of cancer-related health knowledge among different segments of the public across China. The research will identify important information needs and gap, as well as areas where the Chinese public is seriously misinformed about important health issues. The research will provide a general assessment about levels of public health and biological literacy in China, which will be critically important for guiding the development of public health education programs and media [15]. Data from the HINTS-China research program will help identify what the Chinese public knows about relevant health issues and what they need to know to promote cancer prevention and control.

Findings from the HINTS-China research program will help Chinese public health officials evaluate the influences and effectiveness of current health information and education programs in China, identifying what is working and where more work is needed for communicating relevant health information to key public audiences. The data will let these public health officials know what topics need to be included in future health education programs, what channels of communication are likely to reach different segments of the Chinese population, what messages strategies are likely to resonate with different public audiences, and which information sources are most preferred by different audiences for providing them with relevant health information. Data from the HINTS-China research program will be essential for guiding the development of targeted evidence-based health promotion intervention programs in China.

The HINTS-China research program will also provide relevant data for comparison with the US HINTS research program to identify similarities and differences in the ways that Chinese and American publics' access and use relevant health information. There are likely to be important lessons learned about which health communication programs have worked well and which programs have not worked so well in these countries. This information will be used to identify the best health promotion programs to be emulated and the least effective health communication practices that should be improved. These data will provide a basis for international collaboration between the US and China for conjoint health promotion efforts, activities, and policies, as well as provide a basis for encouraging global collaborations between many different countries concerning public health promotion [7, 13]

The longitudinal, repeated administration design of the HINTS-China research program will provide an important source of new data about the changing information and health environments in China. This is particularly important as the rate of change, technological innovation, and international exchanges expand in China. The successive administrations of the HINTS-China questionnaire will help track changes in public access to information, use of communication channels, increases in public knowledge about health issues, as well as identify emergent new health trends and issues that need to be addressed. The survey will also provide baseline data and biennial update comparisons to evaluate health promotion progress in China for promoting cancer prevention and control. Finally, this exciting international research collaboration opens the door to expanding the HINTS research program to many other countries around the world to help promote global health.

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Development of a New Interface System for Elderly People in Daily Life

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***Abstract*— This report proposes a new support system that allows elderly people to live with a sense of security without the help of other people. In this system, it is possible to watch closely the condition of elderly people from a distant public institution by using sensors. Furthermore, this system presents the relevant information in order to maintain the physical condition of the elderly. By performing an experiment using this system, this paper proves that the proposed system would be useful for the support of elderly people.**

Keywords- Elderly; Elderly support system; Welfare technology; Remote sensing; Unwearable sensing; Human motion

I. INTRODUCTION

The number of elderly people is rapidly increasing in both developing and developed countries. It is necessary to establish methods for taking care of many elderly people through a social system. There are many reports about characteristics of human motions in daily life [1-3]. However, there are only a few reports on measurement of elderly people's behavior in daily life situations [4-9]. To establish more adaptable care systems for elderly people, it is important to attempt measuring and analyzing human behaviors and motions in daily life.

In our laboratory, we study the development of support systems for the elderly people. This paper proposes a new support system that analyzes human behaviors and motions and detects a change in the physical condition of an elderly human in the house. It is thought that it is important to research elderly people's behavior in daily life and investigate it thoroughly for developing and establishing a support system.

II. SYSTEM ARCHITECTURE AND QUESTIONNAIRES

The new support system is a Living Situation Monitoring System. The concept diagram of this system is illustrated in Figure 1. The system is fundamentally composed of sensor units, a controller unit and a supervisor unit. Several sensor units and a controller unit with two antennas were placed in the house of solitary elderly people.

Also, this support system has a communication tool. This tool was used when the Health Management Center sent the information of a local community event to elderly people. Figure 2 shows the operation screen of the Health Management Center when they send the information. Figure 3 shows the operation screen on the side of elderly people.

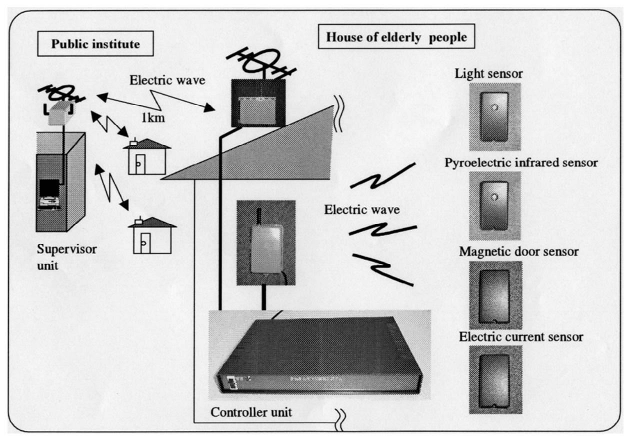

Figure 1. Concept of the monitoring system of living situation.

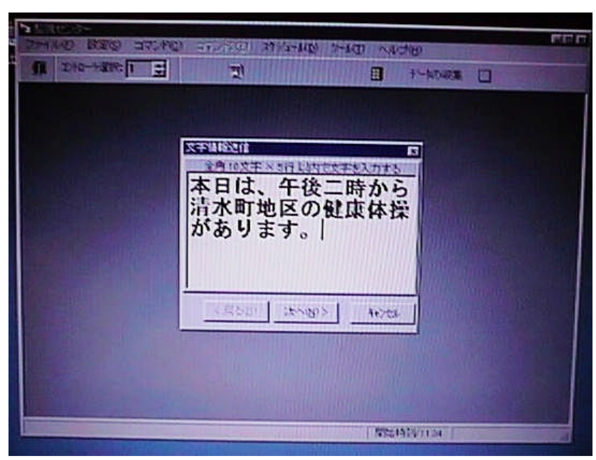

Figure 2. Operation screen on the side of Health Management Center.

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Figure 3. Operation screen on the side of elderly people’s house.

The sensor units consisted of four types of sensors: a pyroelectric infrared sensor, a magnetic door sensor, an electric current sensor and a light sensor. For example, a pyroelectric infrared sensor was able to perceive any human motion by detecting the IR emission from a human body. Also, using an electric current sensor, it was possible to record some actions in human life such as turning on/off the switch of a television, an electric heater, and so on. Using these sensor units, human behavior could be detected. These data were transmitted to the controller unit using a wireless telecommunication method. In the controller unit, these data were analyzed in order to check the physical condition of an elderly human in the house. Several sensors detected human motions in real time, and the detection results were stored in a controller unit. Furthermore, all data in the controller unit were sent to the supervisor unit. In the supervisor unit, the data were classified into each subject’s database and were accumulated. A characteristic pattern for each person, including time series variation of detected values, was extracted from each person’s data using only the pyroelectric infrared sensor.

As the new system was developed, preliminary experiments were performed to examine detection accuracy. The subjects were eight elderly people who lived in solitude away from their family.

In addition, questionnaires were developed to understand the elderly people’s life style and validated. In the first questionnaire, there were about 70 questions about their daily life everyday for a month: wake-up time, bedtime, eating time, times of going out, and so on. In the second questionnaire, subjects were told to list every night what they actually had done on that particular day.

III. RESULTS AND VERIFICATION EXPERIMENTSD

3.1 System architecture and questionnaries

Figure 4 shows the detection results by pyroelectric infrared sensor with the characteristic pattern which was transmitted back to the controller unit. It was possible that, by comparing the measured data using the sensor units, the physical condition of the elderly people could be estimated continuously. As a result, it was possible that the sensors detected human motions like moving from one room to another, and actions like turning on/off the switch of a television.

Figure 5 shows the diurnal detection results by pyroelectric infrared sensor. This result shows exercise tendency of elderly people on several weeks.

Figure 6 shows the number of diurnal use of resting room during daylight, late-evening and first light. It was possible to understand the bcondition of elderly people.

Figure 7 shows the result which was time of gong out everyday.

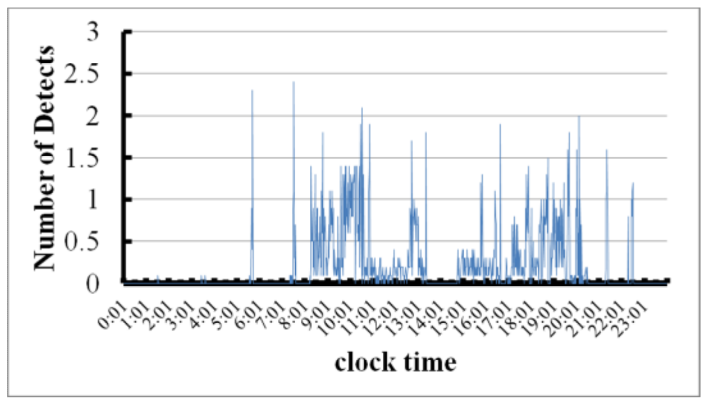

Figure 4. Number of detects in one day.

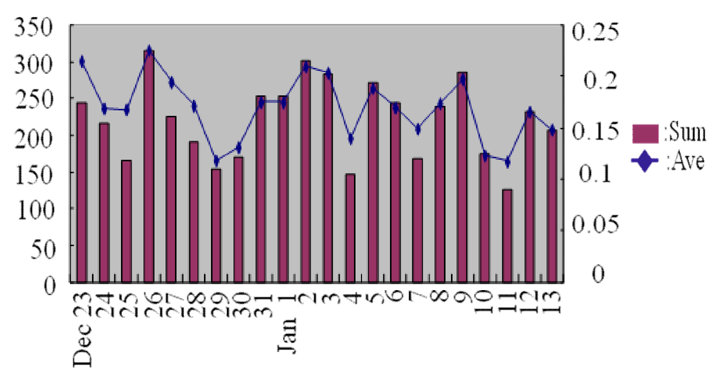

Figure 5. Amount of diurnal exercise.

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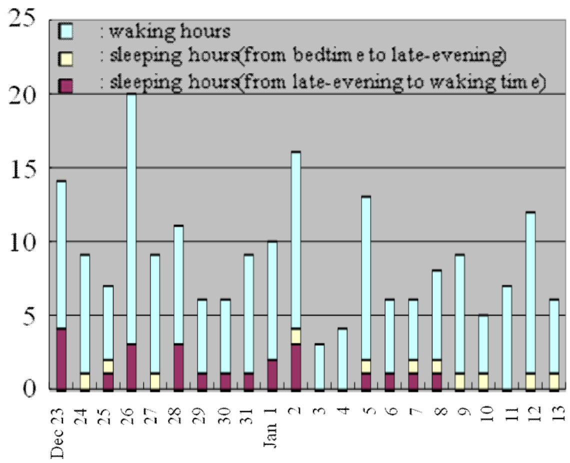


Figure 6. Number of diurnal use of resting room.

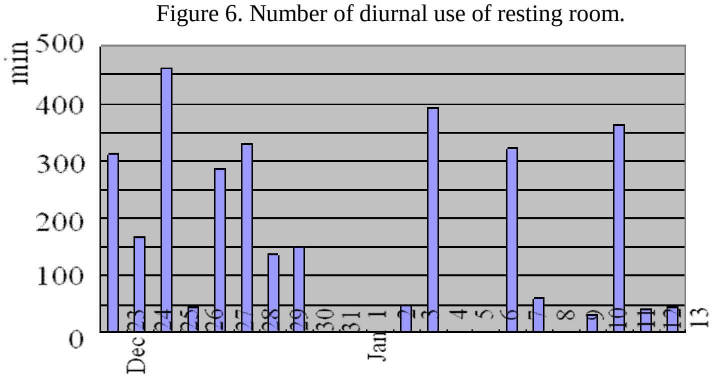


Figure 7. Diurnal behavioral record (time of outing).

From the results of questionnaires, there was evidence that the characteristic pattern was influenced by a change of the elderly people's individual life environment. It was necessary that the system could extract and keep in memory in the supervisor unit several characteristic patterns as the environment around the research subjects changed. Also, it was thought that the characteristic pattern was influenced by the change of an elderly individual's weekly life style. Most of the elderly had habits that given behaviors should be carried out on a certain day of the week. For example, elderly people periodically went to the bath of a public institution on particular day of the week.

In the experiments, several sensor units and a controller unit with two antennas were set up in the houses of solitary elderly people. The subjects were eight elderly people and the number of sensor units was about 15 in each subject's house. Figure 8 shows an illustration of the location of sensor units in an elderly person's house. The number of sensors increases or decreases depending on the number of rooms and the layout of the house. The experiment was carried out in two areas. The center of Takaoka City and Oyama Town were chosen, in order to examine whether the environment around the house was significant or not. In each area, there were four subjects and one supervisor unit. A supervisor unit was located at a public institution within 1 km of the subjects' houses in each area.

In addition to detected results, analysis was carried out with the measured data using sensor units and the results of the questionnaire. Then, using one result of the analysis, we constructed a mathematical model using the neural networks (NN). We investigated other result but one for constructing NN, and realized that the system conjectures one elderly individual's behavior of a day. The analyses using NN software (NEUROSIM: Fujitsu Co., Ltd) were used to conjecture whether subjects were out or at home and were awake or in bed. In analysis of subjects' going out, we used Hierarchical Neural Network including input layer, hidden layer, and output layer. Thirty-five input signals were composed of detection results from five pyroelectric infrared sensors at given times and around 30 minutes by 10 minutes. Output signal was the probability that subjects went out. In analysis of going to bed, we constructed hierarchical NN including input, output and two hidden layers. Sixty-six input signals were composed of detection results from five pyroelectric infrared sensors at given times, around 60 minutes by 10 minutes and clock time. Output signal was the probability that subjects were at rest.

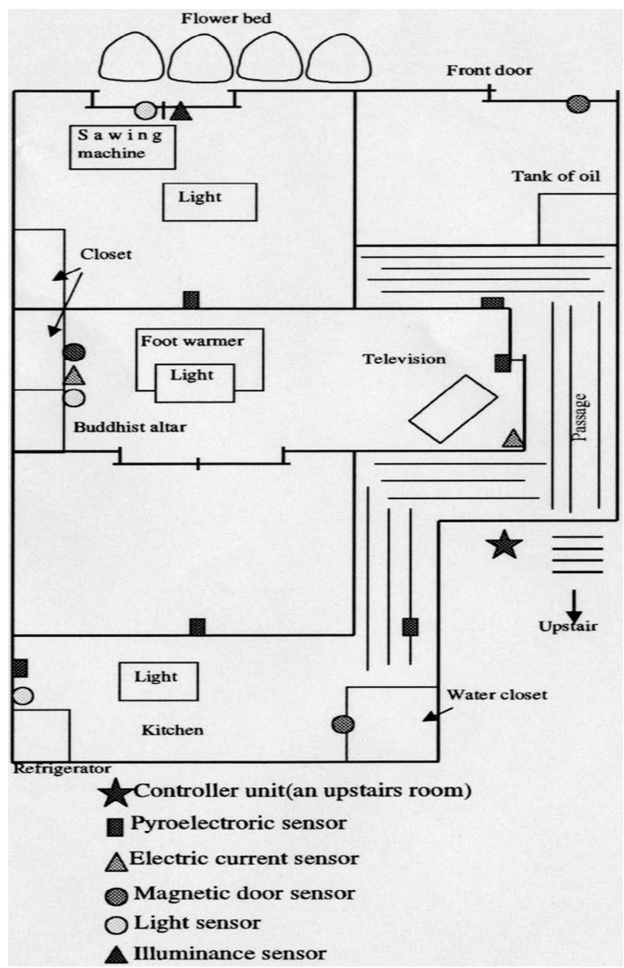


Figure 8. Disposition of sensor units.

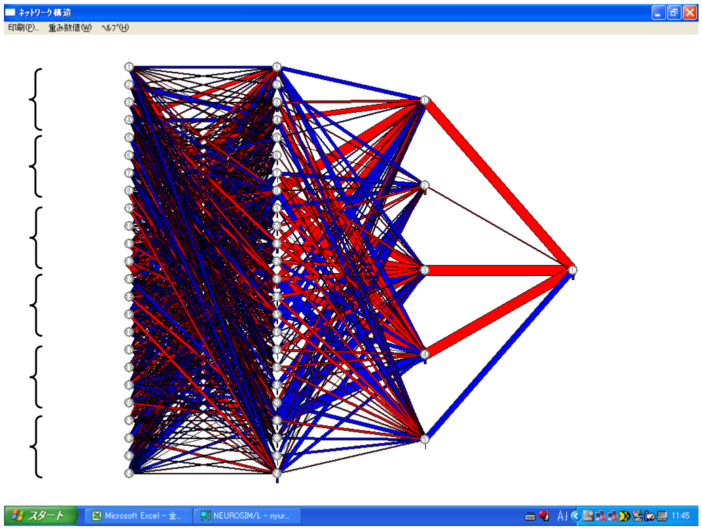
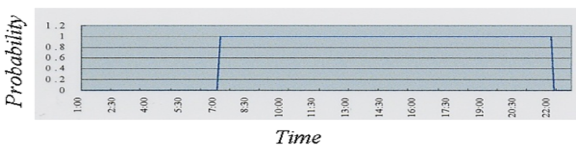
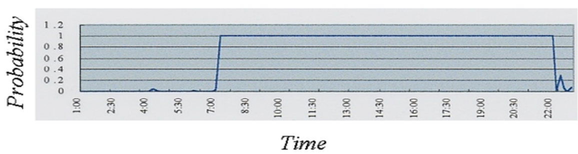


Figure 9. The example of neural network model.

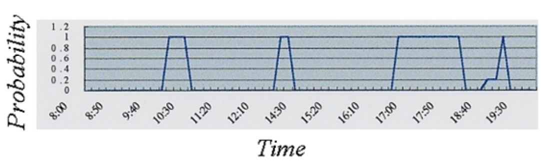


(a) The probability from a questionnaire

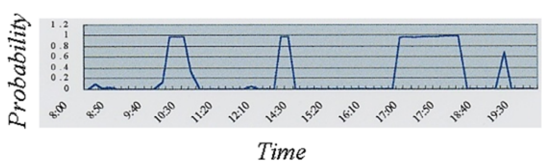


(b) The probability conjectured by analyzing unit

Figure 10. The probability that a subject has gotten up in one day.



(a) The probability from a questionnaire



(b) The probability conjectured by analyzing unit

Figure 11. The probability that a subject has gone out in one day.

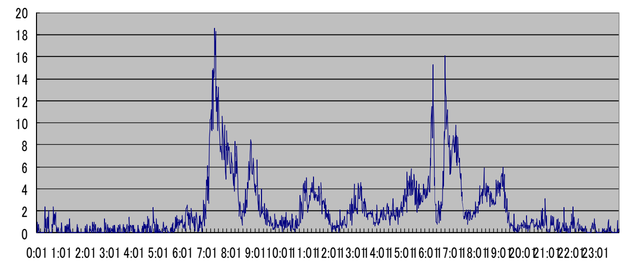


Figure 12. Good condition data from March 14 to April 29 in 2000.

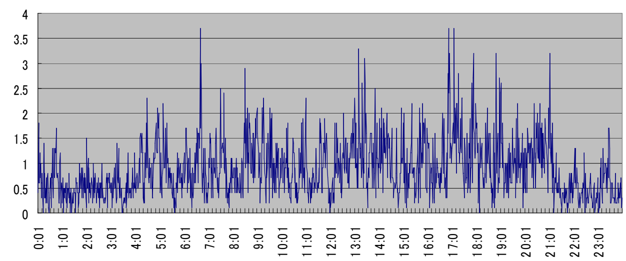


Figure 13. Bad condition data from May 1 to May 26 in 2000

3.2 *Results of verified experiments*

Figure 9 is the example neural network model to analyze for the probability of human behavior based on detections. The neural network was constructed by three layer model. The first layer contained 24 inputs. The second layer contained 24 nods. The third layer contained 2 nods. The neural network model was learned by data for two month for each subject.

Figure 10 shows a result for the probability that a subject has gotten up in one day. Upper Figure 10(a) shows the probability form only questionnaire. Lower Figure 10(b) shows the probability form a neural network model similar to Figure 9. In the questionnaire of the same day, the subject got up at 7:10AM and went to bed at 10:00PM. The probabilities were about 0.003 at 7:00AM, 1.000 at 7:10AM, 9.999 at 10:00PM, and 0.009 at 10:10PM. But the probability at 10:20PM was 0.289. Figure 11 shows one that a subject has gone out in one day.

Figure 12 shows a summation of detection when a subject's condition was good in one day using the new support system. In this result, the subject starts daily exercise at about 7:00 AM every day. Especially, the behavior pattern was detected after 7:00 AM using the new support system. For another subject, behavior pattern was detected each subject using the system. These behavior pattern varied, but the behavior pattern was unified by each subject like in Figure 11. Also, it seems that the various related not environments but subjects. On the other hand, Figure 13 shows a summation of detection when the same subject's condition above result was bad, because this results were recorded just before this subject was hospitalized. In this result, it is not sure when the subject starts daily exercise and shows that the count of detection is lower level than the result of Figure 12; but another behavior pattern was detected using the new support system. For other subjects, behavior patterns were detected each subject using the system. In Figure 13, the behavior pattern is not the same to the behavior pattern in Figure 12 about the same subject. So, we ensure that a difference between a behavior pattern for good health condition and a behavior pattern for a bad health condition was detected using this system. So, it is considered that it is possible to make a judgment about elderly people's health condition.

IV. Discussion

Using the new support system, it was possible to detect elderly motions in life. The most important thing in this system was to detect elderly ones with non-wearable sensors. In addition, play-out and uplink of detected data were performed by wireless connection between both sensor units and controller unit, and between controller unit and supervisor unit. After experiments, we constructed the neural network, and conjectured elderly motion and individuals' particular patterns. Results from neural network analysis were correlated to detected motions and questionnaire responses.

Recently, many companies have become interested in remote sensing for elderly people's healthcare and conducted remote sensing with wearable sensors [10,11]. But, in this case, there was physical limitation, and the elderly went about their daily life with inconvenience and uncomfortable feeling. It was an important advantage in this system that remote sensing was performed by non-wearable sensors. In addition, we challenged experiments with novelty, and measured many data at the same time. Hence, this system was put to practical use, and we obtained a patent for this system.

However, it has been pointed out that this result in sensing humans was still not adequate. It is necessary to measure motions more precisely, because what were detected in this experiment were just motions. In terms of detecting going out, waking up, and going to bed, it was thought to achieve a certain level of result. However, it is requisite to measure subjects' behaviors and movements to observe heir daily life in the real sense of the term. At the same time, human motion was not always considered as measuring changes in their physical condition. In addition, this system was developed with the aim of long-term health management, which is detecting before deterioration of health. This system appears very useful for daily checking based on this standpoint. Additionally, it is thought to detect troubles in about ten minutes by comparing usual patterns which was stored in the controller unit. Furthermore, a system corresponding to emergencies, for example falling, is still being developed. It is absolutely imperative to upgrade this system for detecting the physical condition.

In our laboratory, we are continuing research and development on the system to detect biological signals, for example, heart rate, sphygmus, and body temperature by remote sensing. By translating this system into practical applications, there is a possibility that it would appear that early symptoms in disorders can be detected by remote sensing. Thus, system managers and the elderly themselves can prescribe measures. Currently, we are working practical trial into operation, and lead to the final step in this trial.

V. Conclusion and Future Work

For the purpose of practically applying our new system for elderly people, questionnaires and two experiments were carried out. From the results of the questionnaires, we realized that the characteristic pattern was influenced by a change of the elderly' individual life environment. Therefore, it was necessary that several characteristic patterns be extracted and kept in the memory of the supervisor unit in case the environmental changed. In addition, from the experimental results, it was ascertained that this support system could measure and analyze elderly people's behaviors. According to these results, it was possible to watch closely the condition of the elderly people from a distant public institution. These results indicated that the system was useful for an elderly support.

Now, some functions of this system are used in at least 20,000 houses of the elderly people in Japan, and is playing significant part in their life. Meanwhile, research on detecting elderly's physical condition by this system continues in our laboratory [11].

Acknowledgment

Shunji Matsuoka, Kazuo Yoshida, and Kaoru Iketani at Tateyama System Co., Ltd are deeply acknowledged. Hideto Taya and Hajime Ogi at Advanced Industrial Science and Technology and Kazuo Nakamura, professor at Nagaoka University of technology also gratefully acknowledged for their useful advise to this study. The study was supported by a grant from New Energy and Industrial Technology Development Organization.

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Fundamental Study to New Evaluation Method Based on Physical and Psychological Load in Care

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***Abstract*—Recently, the aging population has increased in Japan and world-wide countries. As a consequence, a wide variety of welfare devices and systems have been developed. However, the evaluation of welfare systems and devices is limited only to stability, intensity and partial operability. The evaluation of usefulness is insufficient. Therefore, we will attempt to establish a standard to evaluate usefulness objectively and quantitatively on the basis of including non-verbal cognition. In this paper, we measure the load of sitting and standing movements by using EMG (Electoromyogram) and 3D Motion Capture and set a goal to establish an objective evaluation method. We think that establishing an objective evaluation method is necessity to develop useful welfare devices. We examine the possibility of assessing load and fatigue from measuring brain activity by using NIRS (Near Infra-Red Spectroscopy). The idea of universal design is widespread in welfare devices and systems. Measuring requires the verification of all generations. However, our study measured younger subjects as a first step because they had enough physical function. Considering younger subjects as a benchmark is appropriate for creating an evaluation method.**

Keywords- Evaluation; Movement; Exercise; 3D Motion Capture; NIRS; EMG; Care; Welfare Technology; Usefulwelfare device evaluation; Evaluation method.

I. INTRODUCTION

As aging population is increasing in Japan and world-wide countries, welfare systems and devices are rapidly developing, and various devices are manufactured because of this increased popularity. Also, the market of welfare devices and systems is expanding. However, the evaluation method is limited to stability, strength and a part of operability for individual systems or devices. This means that an evaluation methodology for the usefulness of these devices and systems was not established. Therefore, we will attempt to establish a standard to evaluate usefulness objectively and quantitatively on the basis of cognition such as physical load, reduction of fatigue and postural stability. In particular, in considering universality, it is necessary to measure human movement in daily life. Movement was not measured using a particular device, but by routinely-performed movement in daily life.

We examined the possibility of evaluation by measuring physical load due to activities of daily living using 3D Motion Analysis System and EMG. Also, we looked into the possibility of quantitative evaluation of tiredness and load on the basis of brain activity using NIRS. We considered that physical and psychological load are linked to cognition, including non-verbal cognition. In this paper, the purpose of the experiments are to evaluate motion focusing on sitting and standing movements, which are usually done in our life, by using 3D Motion Analysis System, EMG, NIRS. We consider that humans feel physical and psychological load during life motion. We tried to measure the physical load by using 3D Motion Analysis System, EMG. Additionally, we tried to measure non-verbal cognition about psychological load by using NIRS.

Subjects were healthy males in their twenties, because elderly people with various types of disease are inept in quantitative evaluation.

II. EXPERIMENTAL METHODS

A. Evaluation by using 3D Motion Analysis and EMG

We simultaneously measured the 3D position and muscle potential of subjects during tasks by using 3D Motion Analysis System (nac IMAGE TECHNOLOGY Inc. products-MAC3DSYSTEM [1]) and EMG (KISSEI COMTEC Inc. products-MQ16 [2]).

Regarding measuring the 3D position, 8 Infrared cameras were placed around each subject, and 27 makers of the body surface were set on the basis of Helen-Hayes Hospital Marker set (Figure 1). In measuring muscle potential, measurement regions were tibialis anterior muscle, gastrocnemius muscle, quadriceps femoris muscle, hamstring, flexor carpi ulnaris muscle, extensoe carpiulnaris muscle, triceps branchii, latissimus dorsi muscle of the right side of the body because these muscle were deeply associated with standing and sitting movement. Also, wireless measurements were used so that the subject was constrained as little as possible. As sampling frequency, 3D Motion Analysis System was 100Hz, and EMG was 1kHz.

The subjects were three males in their twenties. They were asked to read and sign an informed consent regarding the experiment.

In this experiment, each subject repeated one series of movements, which was to transfer from the chair to seat face of the welfare device (IDEA LIFE CARE Co. Ltd products-NORISUKEsan [3]) and opposite one with alternating between standing and sitting, five times per one measurement. Seating face of welfare device, which was designed to assist transfer movement, was manipulated by a simple method and appeared on the top of chair.

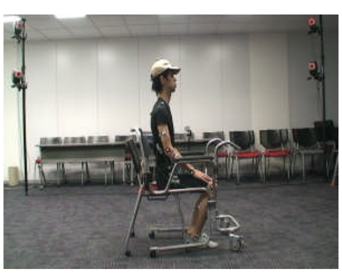

Figure 1. Experimental View of 3D motion Analysis and EMG

Subjects heard a buzzer every second and kept a constant speed of motion to satisfy certain measuring conditions. Also, they transferred from seat face to chair or conversely every 8 seconds with consideration for movement of elderly persons. The operation of the welfare device was performed by an operator other than the subject.

B. Evaluation by using NIRS

We measured brain activity during motion with the purpose of establishing an evaluation method based on generality (Figure 2).

The subjects were six males in their twenties. They were asked to read and sign an informed consent regarding the experiment. The measurement apparatus was NIRS (SHIMADZU CO. Ltd products-FOIRE3000 [4]). The measurement region was at right and left prefrontal cortex.

1) Measuring brain activity during transfer with standing position (task1)

For this measurement, the subjects used a welfare device to perform transferring to a standing position. For this measurement, each subject sat on seating face of the welfare device appeared on the top of chair after raising the hip until kneeling position. Also, each subject performed the inverse motion of transferring from seating face to the chair. The time design was rest (5 seconds), task (10 seconds), and rest (5 seconds). This time design was repeated 30 times. The rest time was used to stabilize the brain activity.

2) Measuring brain activity during transfer with half-crouching position (task2)

For this measurement, the subjects used a welfare device to perform transferring to a half-crouch position. For this measurement, the subjects sat on seating face of welfare device appeared on the top of chair after raising hip until kneeling position. Also, the subject performed inverse transfer from seating face to chair.Time design was rest (5 seconds), task (10 seconds) and rest (5 seconds). This time design was repeated 30 times.

In the experiments of task1 and task2, the operation of the welfare device was performed by an operator other than the subject. Before these measurements, the subjects adjusted to transferring using the welfare device.

3) Measuring brain activity during keeping a half-crouch position (task3).

The subjects performed two tasks in this measurement. During task3-1, each subject sat on the seating face of the welfare device with eyes open. During task3-2, they kept a half-crouch position.

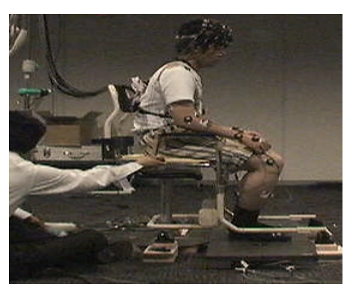

Figure 2. Experimental View of NIRS

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The subjects alternated task3-1 and task3-2. Also, the subjects took resting time between the two types of motion with their eyes closed. The time design was: rest (5 seconds), task3-1 (10 seconds), rest (5 seconds), task3-2 (10 seconds) and rest (5 seconds). This time design was repeated 15 times.

III. EXPERIMENTAL RESULTS

A. Evaluation by using 3D Motion Analysis and EMG

Figure 3 shows the result of transferring which was measured by 3D motion analysis and EMG. In Figure 3, the middle trochanter is the height of the midpoint between right and left trochanter from the floor. The trunk angle is the forward slope of the trunk. Also, following terms are rectifying voltage wave for each eight muscles, which are Tibialis anterior muscle, Astrocnemius muscle, Quadriceps femoris muscle, Hamstring, Triceps brachii muscle, Etensor carpi ulnaris muscle, Flexor carpi ulnaris muscle and Latissimus dorsi muscle.

Next, analysis was performed by extracting the muscle potential during standing and sitting movements from the measured result with reference to middle trochanter and trunk angle and calculating the value of integral during movement. Table 1 shows the ratio of the value integral with the welfare device to the one without the device. Also, we compared the moving distance of median point between using the welfare device and not. Table 2 shows the comparison results in a manner similar to Table 1.

B. Evaluation by using NIRS

As a common result for all subjects, oxy-Hb tended to increase during the task and to decrease in resting state. Therefore, it was thought that a change of hemoglobin density due to task was measured. Figure 6 shows the trend of the channel in which a significant difference was shown. Analysis was performed via one-sample t-test [5,6,7,8,9] by a method similar to previous researches [5,6,7,8,9]. In this analysis, it was necessary to remove other than change of blood flow due to fatigue. So, our method was mainly focused on resting state to compare with the 1st trial and other trials of brain activity. In task1 1 and 2, each of sample data for analysis was 4 seconds after the task (Figure 4). In task 3, the sample data was 4 seconds during task (Figure 5).

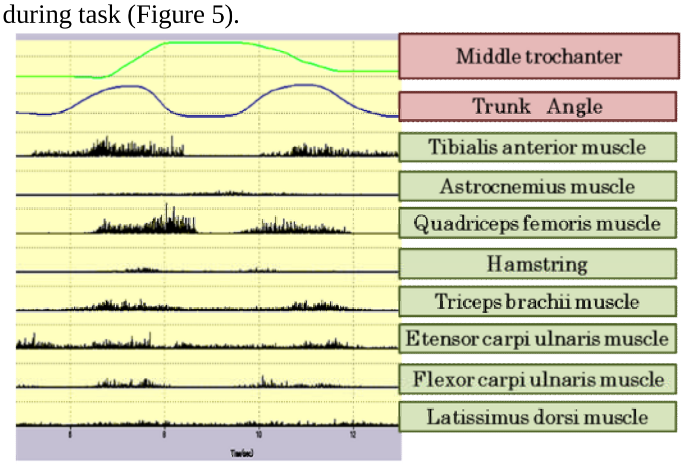

Figure 3. Result of 3D Motion Analysis and EMG

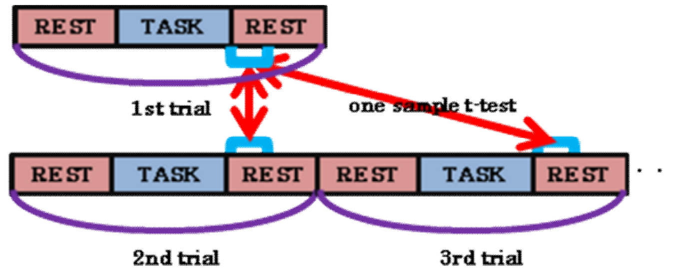

Figure 4. T-test of sample data of task1 and 2

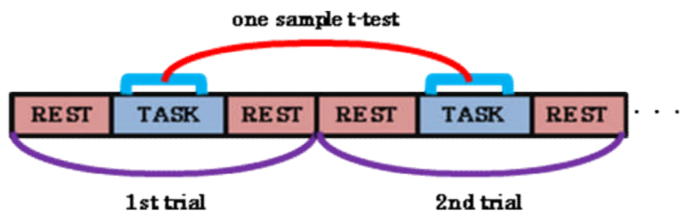

Figure 5. T-test of sample data of task3

TABLE I. COMPARISON OF INTEGRAL EMG

muscle	region	Subject1	Subject2	Subject3
Standing	Tibialis anterior muscle	0.37	0.49	0.64
	Astrocnemius muscle	0.83	0.78	0.97
	Quadriceps femoris muscle	0.66	0.36	0.81
	Hamstring	1.90	0.50	1.07
	Triceps brachii muscle	1.07	3.34	1.01
	Etensor carpi ulnaris muscle	1.08	1.31	0.96
	Flexor carpi ulnaris muscle	1.07	0.89	0.85
	Lattissimus dorsi muscle	0.98	0.87	1.20
Sitting	Tibialis anterior muscle	0.50	0.59	0.80
	Astrocnemius muscle	1.01	0.92	0.94
	Quadriceps femoris muscle	0.49	0.57	0.85
	Hamstring	2.16	1.60	0.96
	Triceps brachii muscle	0.89	0.96	1.07
	Etensor carpi ulnaris muscle	0.79	0.89	0.86
	Flexor carpi ulnaris muscle	0.79	0.86	0.95
	Lattissimus dorsi muscle	1.16	1.18	0.93

TABLE II. COMPARISON OF CHANGE IN MEDIAL POINT

	Subject1	Subject2	Subject3
Sitting	0.89	1.03	0.90
Standing	1.00	0.84	1.08

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In the t-test of the same task, we performed t-test with first time trial and other trial which was from second times to thirty times, and examined relationship of the number of trials and significant differences.

In task 1, a significant difference could be found from the about 10th trials. Figure 9 shows the region confirmed significant difference. In task 2, significant difference could be found from the about 10th trials too. Figure 10 shows the region confirmed significant difference.

Next, we performed t-test with the case of standing position (task 1) and half-crouch position (task 2). In this analysis, a significant difference could be found at prefrontal area (14ch, 17ch, 28ch and 32ch). Figure 11 shows a region confirmed significantly different.

Also, two types of motions which were sitting and keeping a half-crouching position were repeated alternatively in task 3. At first, we performed t-test using 4 seconds during the first trial and 4 seconds during other trials, which were from second to fifteenth in same position. Regarding the result analysis using sample data during sitting position and half-crouching position, there were significant differences at prefrontal area. Figure 12 confirms the significant difference.

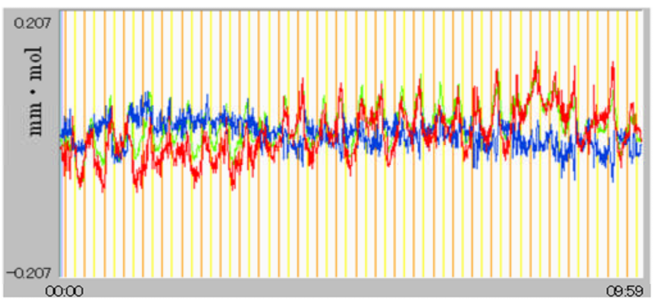

Figure 6. Measuring Result of Task1

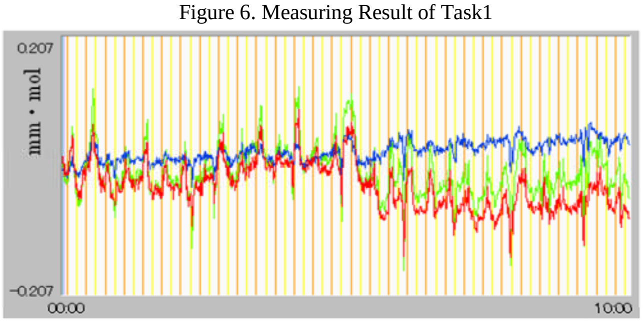

Figure 7. Measuring Result of Task2

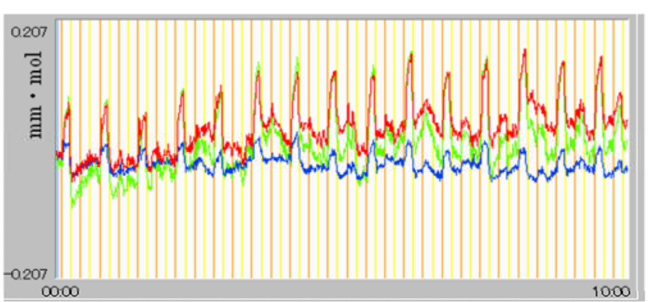

Figure 8. Measuring Result of Task3

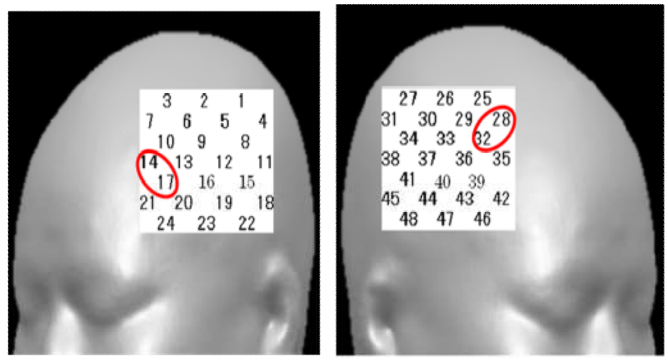

Figure 9. Significant Difference of task1

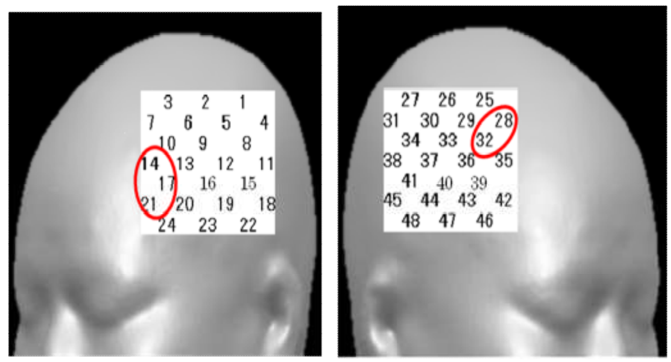

Figure 10. Significant difference of task2

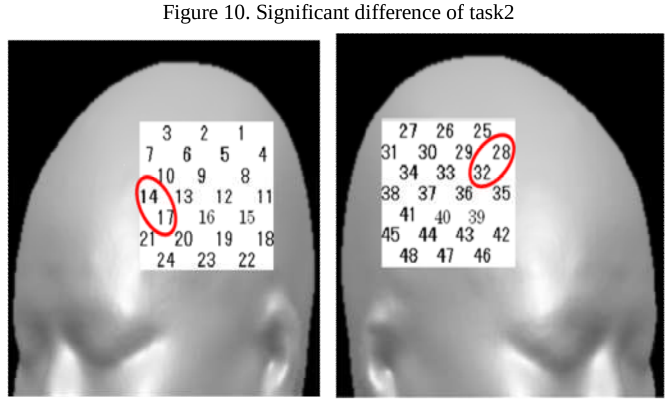

Figure 11. Significant Difference of task 1 and 2

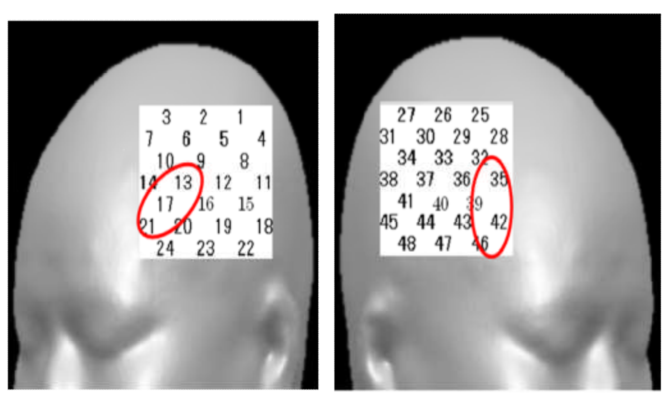

Figure 12. Significant Difference in sitting position

IV. DISCUSSION

1) Evaluation by using 3D Motion Analysis and EMG

From the analysis of the result, it was shown that the value of the integral decreased by using assistive apparatus for transfer. Especially, there was a remarkable decrease in the value of the integral at tibialis anterior muscle, quadriceps femoris muscle. On the other hand, we have shown a minor decrease in one at upper limb and muscles of the back. Also, the moving distance of barycentric position was decreased by the use of the welfare device.

This result was thought to be due to the difference in height between chair and seating face of welfare device. Therefore, it was thought that the use of assistive apparatus is useful to lighten the burden on lower limbs. Thus, it's contemplated that muscle load during standing and sitting movements was decreased and reduced centroid fluctuation to lower the possibility of turnover.

Even if the subjects performed daily movements of standing and sitting with the use of the assistive equipment, we have shown that the integral of muscle potential and distance of centroid change was decreased. Therefore, we proved that there is the possibility of evaluation of daily performance except for movement with the welfare device.

2) Evaluation by using NIRS

In this experiment, we tried to measure quantitatively the physical and psychological strain on the basis of brain activity. Also, we think that brain activity discloses human cognitive including non-verbal. As a result, it was shown that there were differences in brain activity due to the number of trials and postural. At this time, analysis was performed via one-sample t-test using sample of brain activity in resting state, during task, or after task. Hence, the analysis method was to remove disturbance such as body motion and angular variation of neck to the best extent possible although there was the possibility to measure skin blood flow. Therefore, the strain due to tasks was quantitatively measured by recognizing the significant differences.

Also, in previous research, a decrease in the brain activity was reported around #10, 11 [10], as the result of measuring brain activity during Advanced Trial Making Test using PET [11]. Therefore, this result came out in support of previous research.

Of course, it is necessary to increasethe number of subjects at the present stage. In addition, there are problems associated with the experiment, the number of subjects, the method and the measured region. However, in terms of being recognized significant differences at brain activity due to movement, it was thought to show useful result in evaluating quantitatively daily movements.

V. CONCLUSION AND FUTURE WORK

In this experiment, our purpose was to quantitatively evaluate the physical load with focus on standing and sitting movements which are part of usual daily movements, using 3D motion analysis system and EMG.

As the result, it was shown that the integral of lower-limb muscle, such as tibialis anterior muscle and gastrocremius muscle, significantly decreased with the use of the welfare device.

Also, it was reported that there is a positive correlation between anteversion angle of body trunk and movement duration in previous research [12]. But, our experiment method was to estimate the possibility of falling in rising from a sitting position by calculating moving distance of median point. It was confirmed that the possibility of falling was decreased by using the device.

Next, we tried to measure physical and psychological load quantitatively on the basis of brain activity. There were significant differences due to the number of trials, holding position. In this experiment, the analysis method was to remove disturbance such as body motion and angular variation of neck to the extent possible by using the measurement result in resting state as sample. This has been useful in evaluating quantitatively the load due to movement task by being recognized difference in brain activity caused by number of trials, substance of task and holding position.

The main purpose in this study was to evaluate physical load and fatigue quantitatively. We tried to evaluate the change of muscle load due to the difference of motion by simultaneously measuring with 3D motion analysis System and EMG quantitatively.

However, the evaluation of psychological load was necessary, too. In terms of using the welfare device, prolonged use must be taken into account. In this case, it is important to consider not only physical load but also psychological load due to prolonged use from the standpoint of developing the welfare device and keeping up surviving bodily function.

Also, in previous research, separation between physical and psychological loads has been performed. But, our view is that there is a correlation between physical and psychological loads. For this reason, we tried to measure psychological load including physical one based on brain activity to quantitatively evaluate both loads.

For the future, our aim is to establish a method of discussing the usefulness of welfare devices by evaluating the load involved in other daily movements with increasing number of subjects.

ACKNOWLEDGMENT

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This study contributes to become the basis for one of theme of s-innovation program in Japan Science and Technology Agency which was named “Development Fatigue-reduction Technology for Social Contribution of Aged Person and Establishment System for Evaluation.

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Engaging With Online Patient Experiences: Exploring Differences Between Health Groups

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Abstract— **In this paper, data from qualitative investigations with three discrete health groups were pooled in order to identify factors that affect engagement with online material. A total sample of 74 participants (29 asthma sufferers, 25 smokers considering quitting, and 20 personal carers of people with multiple sclerosis (MS)) took part in a study in which they examined and commented on e-health information, including shared patient experiences available online. The findings suggest that engagement is influenced by the availability of off-line information, the ability to cure or control the health condition, and the daily impact the of health condition. Some health conditions (e.g., individuals with MS and their carers) may be more likely than others to engage with websites containing patient experiences, therefore targeting such groups with e-health initiatives could be advantageous.**

Keywords-online patient experiences; engagement; secondary analysis; asthma; smoking cessation; multiple sclerosis carers

I. INTRODUCTION

It is widely acknowledged that the Internet is a commonly used resource for health information. In the UK, a survey by Ellins and Coulter [1] found that second to the doctor, the Internet is a key resource for those seeking health information. Using the Internet as a health information resource has been steadily increasing over the past decade, and is often used as an initial information source before turning to other methods [2]. One form of health information that is sought is other patients' experiences.

Preece [3] noted that "Physicians can provide the facts, but other patients can tell you what it really feels like and what to expect next, in a way that only someone with personal experience can" (p. 63). Other patient experiences of a disease, condition, or treatment can provide information otherwise inaccessible from other sources of health information. From the 2011 Pew Internet Survey, 34% of the Internet users had read someone else's experience or commentary about health or medical issues [4]. Such shared online patient experiences can come from forums, blogs, case studies and testimonials, which can be viewed as text, audio, and video. A recent review of such peer-to-peer online patient experiences suggests their impact can be potentially positive and negative, including providing information, improving health service use, affecting real world relationships, and changing behavior [5]. Empirical studies in this area have focused on a variety of health conditions, but particularly on those considered relatively rare, life threatening, or chronic (e.g., breast cancer [6]; HIV/AIDS [7], arthritis and fibromyalgia [8]). Such investigations have typically focused on a single health condition, and/or multiple conditions considered similar (e.g., degenerative neurological diseases, [9], [10]). Whilst such research is important and insightful, the narrowed focus limits the degree to which comparisons can be made across different types of health conditions.

A large National Institute for Health Research (NIHR) program is currently seeking to explore the role of online patient experience for health decision making in three different kinds of health groups: asthma sufferers, smokers wanting to quit, and carers of someone with multiple sclerosis (MS). These three patient groups were chosen to reflect different types of health conditions (i.e., patients with a chronic health condition, individuals looking for a health behavior change, and individuals who are responsible for someone with a serious life threatening health condition). Whilst collecting data from the groups in three studies, the researchers noticed engagement disparity with the online health information and patient experiences. This was observed in terms of reaction and interest in the materials shown during the study, participant's engagement with similar material before and after the study, and whether they thought online patient experiences were useful. Of the three groups, the MS carers were the most engaged, with the asthma group and then the smokers showing the least engagement.

Although not primary research questions of the program, it became evident to the researchers during their analyses that recurring themes were present across the data, which may contribute to understanding the observed variations. Therefore, the aim of the present paper is to present evidence for three potential factors: 1) availability of off-line information; 2) control over or cure for the health condition; and 3) the daily impact of the health condition.

The remainder of the paper is structured in the following way. Firstly, the method(s) and analysis strategy are briefly outlined, before going on to present the findings of the study. The results are presented in three sections reflecting the three proposed factors that may influence online patient experience engagement. These results are then discussed in relation to other relevant research, before highlighting

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implications and limitations of the study. The paper concludes with some lessons learnt, and suggestions for future research in light of the paper's findings.

II. Method

This paper is based on secondary analysis of data from three studies conducted in the UK between 2011 and 2012 by the authors. The studies employed multiple methods and involved asking participants to look at and comment on websites containing health information, and shared patient experiences. For this study, qualitative data from focus groups and interviews (including follow-up telephone interview in studies two and three) were used. In total, the pooled-sample comprised of 74 participants, including 29 asthma sufferers, 25 smokers considering quitting, and 20 personal carers of people with MS. The analysis was carried out using a similar approach to those adopted by other secondary analyses published within the field (e.g., [9]; [10]), largely derived from guidelines suggested by Heaton [11], and West and Oldfather [12]. Selected data was pooled from the verbatim transcripts to provide relevant material on the selected themes, which had been identified in previously analyses but not relevant to the primary research questions. This process of 'data sorting' [11] was carried out by the primary researcher (CH), who contained a bank of knowledge and 'participatory knowing' [13] of the data, allowing a deeper contextual understanding of the sampled data [12]. The data and themes across the health groups was explored and discussed with the second author (ES, whom was also very familiar with the full transcripts) to ensure interpretations were shared and agreed. Final interpretations were then presented to the remaining two authors (PB, PH), who considered the interpretations of based on their own familiarity with the data.

III. Results

Each theme from the analysis will be presented in turn, including separate sub-sections for each health group to illustrate variations. These findings are illustrated with quotations, using St1, St2, or St3 to indicate the study quotes were derived, and FG (focus group), INT (interview), or FINT (follow-up interview) to indicate which method.

A. Availability of Off-line Information

The present data suggests that if information is widely available off-line or already known by the individual (either through previous information search enquires or general public exposure), then using the Internet and the experiences shared online as a health and decision-making resource may not be utilized or valued.

1) Asthma

For the asthma sufferers, information about the condition was unanimously provided by the individual's physician. Participants felt very confident their physician had given them all the information they needed and in turn, understood the condition well enough.

"I got given an information pack from the doctor that was from the NHS, but have not really looked online. Because they just gave me the pack, so I thought that would have all of the information that I needed" (St3, INT, Participant 7)

Some participants also commented on the input from their family. The condition's heritability meant they were exposed to it from other sufferers and could speak to them off-line for any help or advice.

"I suppose what most information that I got was from my dad…[…]…people in that family who suffer from asthma, and they can offer you some advice"(St2, FG, Participant 3)

Some Internet searches had been carried out by some of the asthma sufferers. However, participants commented that the information they retrieved then, and what they saw during the Internet sessions in the study was generally what they already knew and/or what an off-line source (e.g., physician or nurse) had provided.

"I'd say that I probably have initially in the past when I was kind of first diagnosed and particularly times when I've been ill, more ill with it than I have over times I've maybe looked to see if there's anything I can kind of do but I've never found anything more so I'd say what the asthma nurses told me" (St2, FG, Participant 2)

2) Smokers

From the discussion with smokers, there was a consensus that health information about smoking and quitting can be found from various sources without the need to go looking online.

Participant 3: *"I don't think you need to look for on the Internet. It's on buses. It's on the TV. You don't need to go looking for it they tell you every time stop smoking it's bad for you…"*

Participant 4: *"It's kind of told to you. A lot of people just tell it to you."*

Participant 5: *"You just know it. You don't have to look for it."*

Participant 3*: "It's everywhere like at the doctors on buses metros it's in bus stops. It's just everywhere."*

Participant 4*: "Everything you find on the Internet you know already." (St1, FG)*

Health information on this topic is even available when the smoker is not looking for it. Smokers wanting to find out information about quitting have gone to their physician, pharmacists, or spoken to friends. They have access to many off-line resources and feel that the information they receive online is typically what they already know or can obtain easily from these other off-line resources.

"Yeah first I found some facts I didn't know about which is good, but then they started to get repetitive, for all the websites I looked at, but yeah, I did found out something I

didn't know so it was kind of helpful and in terms of the advice page I looked at, didn't really help. Well, you see them on TV all the time and you know, I don't know, just kind of I knew already." (St1, FG, Participant 9)

3) MS Carers

The perceived amount of information provided by off-line sources, such as physicians, was markedly inferior in this group relative to the other health groups studied.

"Yes, I've used the Internet when he, when we first had the diagnosis, we looked on some of the MS sites to find out some information because we'd had very little information from the hospital…[…]…The only other help we've had is actually once a year contact with the [hospital name] but that dropped out because it wasn't any use." (St3, INT, Participant 3)

Information had been obtained from charities and support groups, through magazines and meetings, but was still felt to be limited. Participants acknowledged that this was in part due to the unknowns surrounding the condition itself.

"No, not the doctor, he was as much use as a chocolate fire guard…[…]… There we are ' I took various Sativex documents to my GP for her to read and decide if I was a good candidate for the drug. When I handed them over she said 'is this this cannabis spray' In other words she didn't know, in other words the GP didn't know. 'I said yes, what do you think' before I could finish that short question, she put her hands up in front of her and backed up quickly, banging into the table. Anyone watching would have thought I was handing her an envelope with anthrax'. And that's the sort of attitude we've got but by people putting this sort of thing up and say look I know this is what the doctors think but this is available to us. And you ought to read up. And we used to get two copies of MS Matters, which is the in house magazine from the MS Society… And so I used to send one down to the doctors surgery and it has improved her appreciation of the illness. But that was the case pretty much." (St3, INT, Participant 7)

Due to professional off-line help seemingly limited across this health group, these participants often felt like information from the Internet was useful (or potentially useful) and the first port of call for finding out about symptoms of the conditions and other people's experiences.

"Yeah, yeah I think nowadays it [the Internet] tends to be kinda a first port of call. I think we kind of resolved that we, the experience we get at the yearly consultants appointment. Usually a 10-15minute conversation with the consultant where she basically tells them what their symptoms have been so far and give it another year. We don't get any more information" (St3, FINT, Participant 1)

B. Control Over or Cure for the Condition

Each group talked about the level of control they felt they had over their or their loved one's health condition, or whether or not it was curable. In this respect, the three health groups varied and this in turn influenced whether they were interested in, or saw value in, the experiences of other patients posted online.

1) Asthma

For the majority of these participants, they perceived their asthma to be well controlled. Many had lived with it for a long time and knew the triggers that could worsen their condition.

"Well I've had it since I was about thirteen so I would say twenty year ago erm ... erm ... I've never really had a ... had it really bad. Only in the winter when I get a cold or something like that. That's the only time it's really bad. But apart from that it's really well controlled." (St3, INT, Participant 6)

When participants had experienced something in relation to their asthma (such as an asthma attack) then they had engaged with the Internet and were more receptive to some of the experiences shared on the websites they examined during the Internet session.

"Just kind of like, like symptoms, whether they're normal or if there's anything like, I used to have a lot of difficulties sleeping so if there's any techniques or anything I could do on a night to make me sleep better, just things like that." (St2, FG, Participant 6)

However, participants had regular check-ups with their physician and generally felt that unless they had a problem, they did not feel the need to look online or act on any information or advice given online. They and their physician or other health professional were able to help control their condition.

2) Smokers

For these smokers, participants believed that quitting was down to them. Participants were aware that whilst smoking is bad for their health and there are quitting aids available, it is entirely their own personal drive that could accomplish cessation.

"I think if you want to quit smoking it's mostly about will power rather than reading about what could happen to you. Everyone knows the facts everyone knows what will happen" (St1, FG, Participant 2)

Participants were not typically engaged with online information of experiences because no one else could do it for them; they themselves have full control of this health issue.

"I think as well you kind of know in your head if you want to quit, so if you want to quit, the chances are like you'll go around yourself, I don't think you need other people's advice, you really want to quit you gonna do it… I think" (St1, FG, Participant 14)

Participants sometimes liked hearing that others found quitting difficult and welcomed any novel tips or advice. However, ultimately, they felt their health condition was entirely under their control and knowing that others could do it may be helpful in terms of inspiration but not a strong reason to return to patient experiences online.

3) MS Carers

Resoundingly, carers commented on the fact that there was yet to be a cure for MS. Research was being carried out, but nothing concretely acknowledged as a drug or therapy had been produced for use within the NHS.

"He [PARTNER] won't admit he got it. He thinks he's gonna get better. Even now he thinks he's gonna get better…[…]… you really realise that you're clutching at straws. There isn't anything out there to help" (St2, FU, Participant 7)

Carers experienced frustration toward the disease because of its variability across different people, which contribute to the difficulty of treating and controlling the condition. The one certainty participants acknowledged was that the condition would get worse and this was beyond their control.

"You know things aren't going to get any better. They're only just going to go downhill." (St2, FINT, Participant 8)

Due to this variability and lack of knowledge of the condition, carers felt that using the Internet to share experiences and learn from one another had significant potential benefits for people living with a health condition.

"I think I think particularly for MS because it's one of those things which's such a broad spectrum…[…]...that a lot time it is that kind of personal information that does make a big difference" (St2, FG, Participant 2)

C. Daily Impact

The daily impact of the condition was another observed theme across the three health groups. Responses highlight a positive relationship between level of daily impact and engagement with online information and experiences.

1) Asthma

For most of the asthma sufferers, this health condition was not regarded as something that had a huge impact on their life and to some, was not even considered a health problem.

"With asthma I don't even think of it as an illness or anything like that it's you know a bit of an irritation that I totally forget once I've taken my inhaler I don't think about it really so I don't search the Internet for anything." (St3, INT, Participant 1)

Asthma was regarded as something these individuals were aware of and took the necessary precautions to ensure it was managed (i.e., take their inhalers). However, once they had done that, the condition could on the whole be forgotten about as it did not impact on their daily life. Some sufferers did think that perhaps they would be more interested in online information and experiences if their asthma was more severe, but otherwise it was something easily controllable with the help of their physician and medication, which in turn means little significant impact on their daily life.

"I mean if I felt kind of more, in a house bound of asthma really affect me I would seek other people's experiences or opinions online but since it didn't seem to be very part of my life I certainly wouldn't use the forums, it work different maybe, more appealing." (ST2, FG, Participant 3)

2) Smokers

The only highlighted daily impact of stopping smoking was attempting to deal with craving. The Internet and reading others experiences online was suggested by one participant as having the potential to be beneficial in this respect.

"I think actually if you just got craving, like I think if you did have a craving for the day, these websites, just maybe kind of distract yourself going onto the website, I think it can help you get pass that initial craving and you go for the next jerk, like half hour to an hour before you start thinking about it, yeah."(St2, FG, Participant 6)

However, largely participants did not see smoking cessation as something that had a daily impact, at least not in a negative way. Therefore, there was little need to engage with online resources.

3) MS Carers

The daily impact of caring for someone with MS was pronounced in this group.

"From my end obviously I've not suffered with the illness but I still, there's an impact on me, there's an impact on the relationship." (St2, FINT, P2)

During the later stages of MS, carers often have to give up employment because the impact of the condition increases to the point where the patient needs full time care.

"Yes, 96, my husband was diagnosed. Erm actually became a non employed carer after 2000. I gave up work then…[…]…and it's just increased the workload, has increased from erm assistance around the house, assistance with getting dressed to erm full 24/7, just about covering every physical need." (St3, INT, Participant 3)

Carers saw the value of using the Internet for information and seeing other people's experiences as it could help them understand their own position as a carer and how they can cope with the progressive impact of the condition on their own daily life.

Interviewer: *"Do you think websites with personal experiences on them are useful?"*

Participant 2: *"Yes. I do. Say I think particularly in the early stages. Just as an ongoing basis...I think that's what's missing sometimes a lot of the more clinical stuff on the websites, there's a limit to the amount of information you can be told about MS. There's a limit to what's known. But there's a lot underneath that. I mean a lot of the questions people ask are 'how's this gonna impact me? Is it gonna break up my life? How am I gonna cope with it?...[…]…This kind of thing. Most of the time the only people who can tell you that are the people who suffer form MS themselves. Em, so yeah I think there is a lot of value in that." (St2, FINT)*

IV. DISCUSSION

The increasing use of the Internet for health information, and in particular, the experiences of others with a specific health condition has spurred researchers from various disciplines to explore this phenomenon. However, evidence from the present research indicates that people with certain health conditions or problems may be more likely to engage with online patient experiences than others. This paper suggests that individuals living with a health condition where: a) little off-line information about the condition is available (e.g., from their physician; b) is non-curable or non-controllable; and/or c) has a high impact of the individual's daily life, are more likely to seek out and engage with shared online patient experiences.

These findings are consistent with other findings that individuals with chronic or debilitating conditions (or their carers) are likely to seek information online [4; 14]. Other research has also shown that the Internet is a preferred resource for health information when patients felt dissatisfied with the patient-physician interaction, particularly when needs (e.g., the provision of information) have not been met [15]. Research has revealed that households would often use the Internet to find out information for their needs regarding health issues that were affecting everyday routines [16]. The present study's proposed factors could explain these higher levels of online engagement in terms of unsatisfactory off-line information (e.g., from a physician) and having a health problem with a daily impact, which is not under the individual's.

In other research, however, Tian and Robinson [17] found that adult cancer patients who visited their doctors more frequently were more likely to pay attention to health information from other mediums (e.g., magazines and on the Internet), even after controlling for condition severity. The researchers proposed that these findings supported the complimentary theory of media use (i.e., use of one media increases the likelihood of using another). More recently, other research has also shown that online support group members, who believed they had high control over their illness, were also more likely to use online resources [18]. These studies seem to contradict the present study's findings.

However, interestingly, in another study on breast cancer patients Sandaunet [20] found that online support group members withdrew from online participation when they no longer felt 'ill enough' or when they were at a particular phase of the illness which felt manageable. It may therefore be the case that these cancer patients felt in control of their condition, and that the daily impact on their lives was insufficient to warrant continued engagement with an online support group. Therefore, it could be that complementary use of media resources are more likely to result when low levels of control and/or daily impact is high, which may vary over time. In addition, utilizing the additional resource of online support groups may contribute to perceived control over the health condition.

These research findings, together with the present paper, suggest that understanding engagement with online health resources is a complex phenomenon, and further research is needed. Of course, even within health conditions there may be individual or dispositional variations in the likelihood to engage with the Internet and seek other online patient experiences (e.g., [20]). However, the present research suggests it may be possible to predict why some health groups may be more likely than others to use the Internet and look for others who are experiencing similar health issues. These findings could have important implications for policy makers, investors, and health providers in terms of future ehealth initiatives. For example, it is often advocated that physicians have a list of recommended websites for referring patients to so they can seek out such information in relation to their condition. However, the present study suggests that it may not be necessary for physicians to do this for every patient they see. Not all patients with health conditions may be equally interested in websites related to their condition. It may only be useful for certain conditions where physicians know there is a limited amount of information or help they can provide to the patient, and/or where they know the impact on the patient's daily life will be high.

For policy makers and investors, these results also suggest where a society or population may already know or be exposed to a lot about a health condition, individuals may feel saturated or de-sensitized to attempts to change their behaviors or decisions in relation to their health condition. Therefore, ehealth policies and strategies aimed at such conditions may provide a smaller return on investment than less well known conditions, conditions that cannot be cured/controlled, and/or may have a significant impact on the individual's daily lives. This is a particularly significant implication when there are limited time and resources available for such ehealth initiatives.

Despite such useful insights from the present study, it is not without its limitations. The data collected represents a UK sample. Other countries have different health care services and provisions, and cultural variations may affect engagement factors. Whilst representing a variety of types of health user, it may be that the health conditions examined

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do not cover all the possible levels of engagement with patient experiences. It is also important to note that for practical and ethical reasons, our sample did not contain any very severe health cases. These limitations impose some restrictions on the generalizability of the results. However, they give rise to important suggestions for future research and collaborations on this topic.

V. CONCLUSION AND FUTURE WORK

From this study, we have learnt that different health conditions may vary in terms of the levels of engagement with online health information and shared patient experiences. In particular, engagement appears to be influenced by the level of off-line information, the ability to cure or control the health issue, and the daily impact the condition. These lessons provide some important implications for policy makers, investors, and service providers on ehealth initiatives, as well as highlighting the potential value that this line of research. Continuing this research across a broader range of health topics would therefore be worthwhile. Future research could also examine the degree of influence of each factor, and whether higher levels in just one factor (e.g., daily impact) would still result in engagement when there are lower perceived levels in the other factors (e.g., off-line information and control/cure of health condition). Longitudinal research would also allow researchers to see how and if engagement varies over time in relation to the proposed factors. Finally, the paper highlights the potential of using innovative methods of recycling existing data. We therefore encourage future pooled case comparisons of existing data to help explore online patient experience engagement, ehealth, and health in general.

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Feasibility of Electronic Health Kiosks to Assess Chronic Disease Status in Remote Areas of Developing Countries

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Abstract— **Developing countries lack the infrastructure for effective health care delivery, especially in remote areas. To prevent and manage the rising burden of chronic diseases in developing countries, health care services must reach even the most remote areas. The study presents the electronic health kiosk (EHK) as an effective and feasible solution to assess chronic disease status in remote areas of developing countries, having India as an example. Cross-sectional data was collected on a convenient sample of 429 subjects, 18 years and over, in urban, slum and tribal settings. Results show high prevalence of overweight subjects in urban settings (31.5%; n=70), a high prevalence of pre-hypertension overall (41.5%; n=178) and hypertension in tribal settings (26.1%; n=28), and high glucose prevalence in 27% (n=116) of subjects overall, and (17.8%; n=19). EHKs can be used to assess these health outcomes in areas that normally are not covered due to lack of infrastructure or health personnel. These health kiosks can be a medium to deliver evidence-based, contextual and tailored multimedia health education modules improving the overall quality of health care among these populations. They can also help to raise awareness about health issues and create meaningful information for public health decision-making.**

Keywords-health kiosk; public health informatics; global health; chronic disease.

I. INTRODUCTION

Chronic disease is a global burden responsible for over 50% of worldwide mortality [1]. It is estimated that, in 2020, chronic diseases will be the cause of 50 million deaths globally [2]. Their prevalence is increasing especially in developing countries, where diabetes alone is predicted to afflict about 298 million people in 2030 [3]. It has been estimated by the World Bank that controlling cardiovascular diseases would lead to improved life expectancy more effectively than trying to achieve WHO's Millennium Development Goals related to selected infectious diseases and maternal and child health [4].

Prevention, however, is still scarcely supported financially and politically through public health programs, even though the potential damage on population health and economies worldwide is evident. In addition to it, many developing countries lack the infrastructure for effective health care delivery, especially in remote areas. Lack of qualified personnel is also a challenge to provide meaningful service, as low wages, insufficient living, and working conditions, are obstacles that prevent the trained workforce to establish themselves in these areas of extreme need [5]. In India, for example, where a shortage of health care professionals normally exists, remote areas are even more underserved. Urban areas in average have 3 times the number of health care providers compared to rural areas [6]. Another example, Brazil has its health resources also concentrated in urban settings, leaving a young and inexperienced workforce to deliver care in more remote municipalities [7]. To contain the spread of chronic diseases in developing countries, it is paramount to find ways to bring quality health care even to the most remote regions.

The aim of this paper is to present the electronic health kiosk (EHK) as an effective and feasible solution to assess chronic disease status in remote areas of developing countries, having India as an example. The paper will be divided in 6 sections. Section I is the introduction. Section II will briefly explore the current state of health technologies and propose the EHK as a solution for delivering health care in remote areas. Section III will describe in detail the EHK used in this study. Section IV will present the methods and instruments used to conduct this research. Section V will identify the most relevant results. Section VI will be the conclusion and recommendations for future research.

II. CURRENT STATE OF HEALTH TECHNOLOGIES

Communication and information technologies have helped to change health care delivery to a model of management centered on the patient instead of the provider. Health care services are now able to reach beyond the traditional clinical settings, arriving to the point of care even in more isolated communities where these services are extremely needed.

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Educating patients through computer technology use has been recognized as an effective measure to develop patient skills and knowledge, and improving chances of appropriate behavior. The necessity of offering better services at lower costs makes the use of computer technology essential to support health education [8]. Health promotion, and chronic disease prevention and surveillance, can be achieved through telehealth technology, which acquires, disseminates and stores health-related information electronically [9]. This technology can be presented and accessed in different formats such as web-based applications, mobile phone and alert systems, and telephone and video conferencing with patients [10,11].

EHKs relieve the health care providers from the burden of providing preventive and continuous health education. Instead, they can then concentrate on the quality of their care, especially in circumstances that require immediate attention. EHKs can deliver interactive health information programs that are tailored to the specific needs of the community or the individual [12]. The ability to continuously tailor the EHK information based on patient's input could be the inexpensive bridge to addressing his need for adequate information, customized to his ever-changing health status.

The advantages of accessibility and a user-friendly interface can make kiosks a powerful tool for promoting health education in communities in both urban and rural settings. They are usually built as free-standing units, which facilitates their transportation and increases the possibility of providing access. They can be placed in health care settings or in any kind of public space [12, 13]. The EHK possesses a simplified interface and can be used by individuals from various backgrounds regardless of class or education level [12]. It also varies in many different levels, such as interactivity and feedback [12]. Kiosks can be an effective way to deliver high quality health care to remote areas in developing countries.

III. THE ELECTRONIC HEALTH KIOSK

The EHK used in this study is a multilingual standalone, internet and cell-phone based system. The kiosk has several calibrated metric physiological sensors that can capture a diversity of medical parameters, including blood pressure, blood sugar and weight. These measured parameters are communicated automatically to the software embedded in the touchscreen EHK. These sensors make EHK a useful and efficient approach to collect data electronically and help assess the actual state of the individual's health. The kiosk can be utilized on its own without any assistance as it is user-friendly, with minimal number of buttons and icons, and the program is very easy to operate and navigate through.

For each individual, the EHK system generates a unique ID to which all gathered data is assigned. Individuals can then create their own username and password, allowing them to log into the system and access their health information at any time and from anywhere. The self-report information gathered can include socio-demographics (such as age, gender, and educational status), health behavior variables (including body mass index, smoking, drug and alcohol consumption), and clinical variables (including current state of diabetes, hypertension and cholesterol, history of medications, and lifestyle) (Figure 1).

The quantitative and qualitative data measured and collected result in a unique health card that provides a snapshot of the individual's multiple risk factors. Further, health information is provided to help address and manage these various risk factors, tailored according to the data collected in the EHK for the specific ID.

IV. METHODS

The study was conducted in a community setting in the city of Rourkela, state of Orissa, in India. Between the months of March and May 2010, a convenient sample of individuals was enrolled from three diverse geographical locations including urban, rural and tribal areas, to explore the utilization of a portable electronic health information kiosk for the assessment of chronic disease health risks, and compare the differences among them. The targeted population included adults older than 18 years, both male and female. Participation in the study was voluntary, and willing subjects were provided with a one-page summary where the study was explained. The study was approved by the University of Maryland Baltimore County Institutional Review Board.

Subjects were asked to use the EHK described previously, which gathered subjective and objective data to understand the distribution of chronic diseases and associated risk in the diverse community settings.

The subjective data gathered included responses to a series of multiple choice questions. These questions assessed location of residence (urban/slum/tribal); age (years); gender (male/female); highest level of education attained (less than high school/some college/graduate and above/none); smoking and alcohol history (presently/in the past/ never); height (feet, inches); ever told by a doctor about high blood sugar (yes/no/I don't know) and if yes, are you currently being treated for your high blood sugar (yes/no/I don't know); ever told by a doctor about high blood pressure (yes/no/I don't know) and if yes, are you currently being treated for your high blood pressure (yes/no/I don't know).

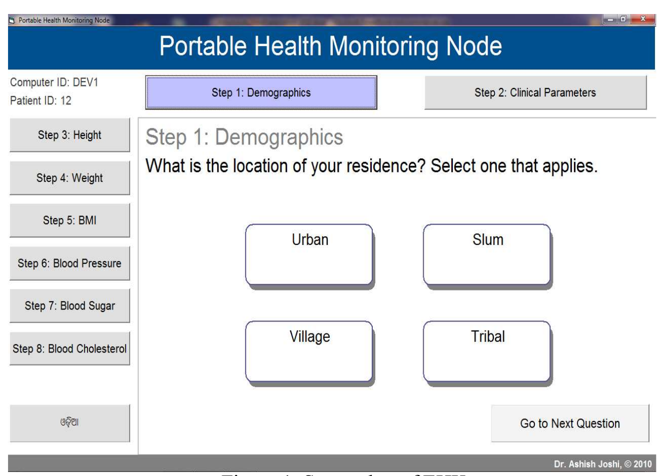

Figure 1. Screenshot of EHK.

Objective data was gathered using the multiple calibrated physiological sensors which measured weight (kilograms), blood sugar and blood pressure. The readings were automatically transmitted to the touchscreen EHK.

Descriptive analysis was performed using univariate statistics with results for the continuous variables being reported as means and standard deviations while results for the categorical variables were reported as frequency statistics as appropriate. Analysis of variance was performed to determine if there were any significant differences in the continuous variables across the different geographic settings including urban, slum and rural. Similarly chi-square analysis was performed to determine if there were significant differences in the proportion of the categorical variables and the geographic settings in which individuals were living. All analysis was performed using SAS V 9.1 and the results have been reported as p-values.

V. RESULTS

Cross-sectional data was collected on a convenient sample of 429 subjects, 18 years and over, in urban, slum and tribal settings. Fifty-two percent (n=222) of the subjects were from urban settings, followed by 23% (n=100) living in slum, and 25% (n=107) living in tribal settings. The average age was 41.98, and the majority of the population was male (61.3%; n=263). Subjects enrolled from slum settings, however, were predominantly females (69%; n=69). Although the majority of the subjects reported some college to post-graduate level of education (54.6%; n =234), most subjects in the slum and tribal settings had no formal education (40% and 36.4%, respectively) or at most high school level (44% and 37.4%, respectively). In the tribal setting, 36.4% (n=39) of subjects were current smokers, and 29.9% (n=32) consume alcohol.

Results showed a high prevalence of overweight subjects in urban settings (31.5%; n=70) (Table 2). Albeit in smaller numbers, overweight subjects were also identified in the tribal (12.1%; n=13) and slum settings (10%; n=10). A high prevalence of pre-hypertension among subjects was also detected (41.5%; n=178). It is important to note that in tribal settings, 26.1% (n=28) of the subjects were diagnosed with stage 1 or stage 2 hypertension. Abnormal blood sugar levels were detected in 27% (n=116) of subjects overall, while in the tribal setting 17.8% (n=19) had high glucose. Results also have shown that 79.4% of subjects (n=85) in tribal setting reported that they don't know if they were ever told to have diabetes by a doctor (Figure 2).

TABLE I. SAMPLE CHARACTERISTICS

Variables	*Total N=429*	*Urban N=222*	*Slum N=100*	*Tribal N=107*
Age	41.98	45.72	41.13	35.02
Female	38.7%	21.2%	69.0%	46.7%
Education level				
High School	27.0%	14.4%	44%	37.4%
Some college /Graduate	47.6%	72.1%	16%	26.2%
Post graduate/Professional	7.0%	13.5%	-	-
None	18.4%	-	40%	36.4%
Smoking History				
Presently	18.6%	13.5%	11.0%	36.4%
In the past	13.3%	18.9%	9.0%	5.6%
Never	68.1%	67.6%	80.0%	57.9%
Alcohol History				
Presently	20.5%	16.7%	19.0%	29.9%
In the past	13.1%	14.9%	11.0%	11.2%
Never	66.4%	68.5%	70.0%	58.9%

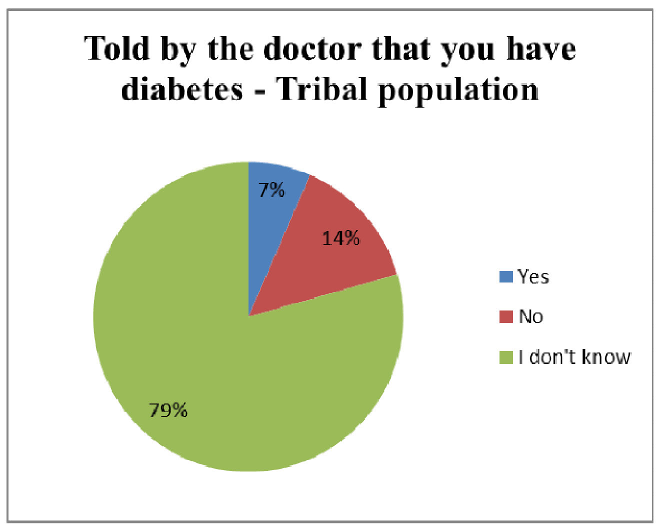

Figure 2. Percentage of answers for information on diabetes status by a health professional in tribal population.

These findings reflect an urgent need to utilize novel accessible and cost-effective technologies that can gather evidence-based data at the grassroots level so that timely interventions can be done to minimize the rising burden of chronic diseases in the rural and remote areas of developing countries.

VI. CONLUSION AND FUTURE WORK

The study results have shown that the prevalence of chronic diseases in tribal and slum communities is considerably high.

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TABLE II. BODY MASS INDEX, HYPERTENSION AND BLOOD SUGAR CHARACTERISTICS OF INDIVIDUALS IN DIVERSE SETTINGS

Variables	*Total N=429*	*Urban N=222*	*Slum N=100*	*Tribal N=107*	*Statistics*
Body Mass Index					**Chi Square =50.175; p<0.001**
Underweight (<18.5)	17.2%	8.1%	21.0%	32.7%	
Normal (18.5-24.99)	56.6%	56.3%	62.0%	52.3%	
Overweight (25.0-29.99)	21.7%	31.5%	10.0%	12.1%	
Obese (30 or greater)	4.5%	4.1%	7.0%	2.9%	
Blood Pressure					**Chi Square =16.365; p=0.012**
Normal (<120 and <80)	28.9%	20.7%	36.0%	39.3%	
Pre Hypertensive (120-139 or 80-89)	41.5%	45.5%	40.0%	34.6%	
Stage 1 Hypertension (140-159 or 90-99)	18.2%	21.2%	13.0%	16.8%	
Stage 2 Hypertension (>160 or >100)	11.4%	12.6%	11.0%	9.3%	
Blood Sugar					**Chi Square =8.157; p=0.017**
Normal (<140)	73.0%	67.6%	75.0%	82.2%	
Abnormal ((≥140)	27.0%	32.4%	25.0%	17.8%	

Results suggest that 1 in 3 subjects in urban settings are overweight, similar to what has been presented in a recent study where rates as high as 40% were measured in some urban areas [14]. Another important finding of the study was the high prevalence individuals in the tribal population with of pre-hypertensive status (34.6%; n=37) and hypertensive status (26.1%; n=28). High glucose levels were also detected in 17.8% (n=19) of subjects in the tribal setting. A very recent study in India, has presented similar prevalence with variations according to different Indian states [15].

The state of Orissa, India, where Rourkela is located, has a population of over 40 million people. According to the 2001 census, 85% lived in rural regions and 22% were tribal populations [16]. Of the Indian tribal population, however, 25% doesn't have access to health services [17]. This is a serious limitation for public health surveillance in India, as risk factors and harmful health conditions are not being assessed in a regular basis. Studies have been consistently detecting a high number of individuals with undiagnosed chronic diseases, such as diabetes and hypertension, among populations in different areas of the country [15,18].

EHK can be a feasible technology to assess burden of risk of chronic diseases at the grassroots level and even in resource poor environments. These assessments can provide us true representation of the risk burden and the evidence based data to make informed decisions and timely interventions for improving the overall well-being of the individuals, the communities and the environment they live in. However, due consideration should be given to design and develop accessible and tailored technologies that take into account health literacy of the individuals and utilize targeted mode of delivery of health promotion messages for better adoption of these technologies. Further research is warranted to determine the role of utilizing EHK as a medium to bridge the gap among individuals with different risk factors in various settings.

Limitations of the study include the use of a convenient sample, although similitudes in measured characteristics with recent studies may attest to the representativeness of the data [14, 15, 18]. Results showed less percentage of females participating in the urban setting as compared to the slum or tribal settings. This difference might be due to more number of females being employed in the urban setting as compared to the others. In addition, cultural variations in the diverse settings might also account for these differences in participation. Another limitation was the lack of cost-effectiveness assessments for the use of EHK in these settings and the long-term impact on population outcomes. These assessments are currently being evaluated in the ongoing studies.

The EHK can be the multifaceted solution to the difficult obstacles faced by public health in developing countries. There are current plans to implement EHK by engaging community health extension workers in the diverse Indian settings including urban, rural, slum and tribal. Further, the development of a randomized controlled clinical trial is in course. The aim is to test the EHK efficacy as an interactive, personalized, culturally adaptive, contextually relevant, accessible and cost-effective platform. Another goal will be to help improve health outcomes among populations in resource-poor environments.

EHK can be used to assess chronic disease status in areas that normally are not covered by a developing country public health system due to lack of infrastructure or health personnel. EHK can be a medium to deliver evidence-based, contextual and tailored multimedia health education modules, and could improve the overall quality of health care among these populations as further research is needed to determine this.

For governments and institutions to act, enacting policies that can improve health outcomes in disadvantaged areas, first they need the data and the evidence to support it. EHK can be an instrument to raise awareness about health issues and create meaningful information for public health decision-making.

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