GLOBAL HEALTH 2015

The Fourth International Conference on Global Health Challenges

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Nice, France

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GLOBAL HEALTH 2015

Forward

The Fourth International Conference on Global Health Challenges (GLOBAL HEALTH 2015), held between July 19-24, 2015 in Nice, France, continued a series of events taking 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.

The conference had the following tracks:

- Trends and Practice
- Challenges
- Fundamentals
- Technology
- Medical Systems and Technologies

Similar to previous editions, this event attracted excellent contributions and active participation from all over the world. We were very pleased to receive top quality contributions.

We take here the opportunity to warmly thank all the members of the GLOBAL HEALTH 2015 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 that dedicated much of their time and effort to contribute to GLOBAL HEALTH 2015. 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 also gratefully thank the members of the GLOBAL HEALTH 2015 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope that GLOBAL HEALTH 2015 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the area of global health challenges. We also hope that Nice, France, provided a pleasant

environment during the conference and everyone saved some time to enjoy the charm of the city.

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Health Communication and Information Exchange in a Vascular Surgery Patient Trajectory

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Abstract. **Health communication and information exchange is important in public health. Despite the fact that adequate health information is a patient right according to Norwegian law, complaints from patients to the authorities on lack of information and communication are frequent. The purpose of the paper is to discuss health communication and health information exchange for patients undergoing vascular surgery for abdominal aorta aneurism (AAA), with particular focus on the communicative practices in a typical patient trajectory for this cohort. Both verbal communication and written information exchanged through health information systems during the patient trajectory are included in the data. The project is theoretically and analytically inspired by linguistic and discourse analytical perspectives on information and communication about health.**

Keywords- Health information exchange; health communication; digital health; patient trajectory; aorta aneurism.

I. INTRODUCTION

Health communication is important in public health [1]. Information exchange and health communication is essential for patients' confidence in the healthcare services. Trust is a basic premise for good patient care, and is an important patient right in Norway. The Patient Rights Act [2] is specifically designed to "promote trust between the patient and healthcare services, to promote social security and respect for the individual patient and the user's life, integrity and human dignity". However, the feedback from patients and clients demonstrates that information exchange and health communication are areas for improvement. Also the Ombudsman and the authorities emphasize that communication needs to be improved [3].

Structuring patient care in patient trajectories is a strategic move to make patient care predictable for patients. A patient trajectory is "the chronological chain of events that concerns the individual patients with different healthcare systems"[4]. Good patient trajectories are characterized by the fact that these events are put together in a rational and coordinated way to meet different patient needs. Central Norway Regional Health emphasizes in its strategy that: "the treatment course should be predictable, coherent and effective for patients and their families" [5]. The glue in the patient trajectory is the health communication and information exchange between health professionals and patients. A predictable patient trajectory for patients requires that information exchange and health communication between healthcare providers and the patient is adequate at all levels, both in primary and specialist health services.

Health communication and information exchange is complex in modern healthcare organizations that are technology-intensive and consists of professionals with different roles and tasks. The healthcare sector is an arena that is constituted by different communication practices, such as oral conversations (doctor-patient conversations, expert talks, the head-staff conversations), written texts (invitation letters, information letters, discharge summaries, procedures). The use of medical technologies and information and communication technology tools with different purposes (X-rays, ultrasound, imaging systems, patient administrative systems, ePrescription, curve solutions, welfare technologies) is extensive.

Good communication between individuals and among participants in multidisciplinary medical teams is essential for the diagnosis to be correct, for the treatment to be relevant and for the information to be maintained. The introduction of ICT systems, medical technologies and welfare technologies lead to organizational and practical work changes. These changes challenge established communicative practices. Preferably, changes in communicative practices should result in improvements in information processing and dissemination, precision in diagnosis and effectiveness of treatment. Unfortunately, we have seen examples that it rather can result in ambiguity, confusion and resistance in terms of application and dissemination.

A successful introduction of new technologies such as ICT, medical technologies and welfare technologies requires knowledge of the communicative practices that technologies will help to address. Therefore, mapping studies of communicative practices through a patient trajectory are required. Examining the single-case studies may enable us to

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understand what improves or degrades the established practices.

The objective of this paper is to discuss health communication and information exchange in the chain of activity types in patient trajectories for patients undergoing surgery for AAA. The goal is to map and describe the activity types during a patient trajectory, from hospitalization and surgery to discharge. The research questions are:

1) What characterizes the chain of activity types in a typical patient trajectory?
2) Who are the participants in the activity types?
3) Which are the communicative practices in the activity types?

Section II offers a discussion about the theoretical perspectives of the study. Section III presents the methodological approach. The results are presented in Section IV, and discussed in Section V.

II. THEORETICAL PERSPECTIVES

The theoretical and analytical approach in this project is *discourse analysis*, which offers concepts and tools for describing communicative practices at different levels. Traditionally the concept of discourse is understood as language use in oral or written communication in a social context. Candlin [6] points out that oral and written language has a constructive and dynamic role when it comes to structuring knowledge, as well as for structuring social and institutional practices in which knowledge is created and used. Discourses influence, and are influenced by social practices, and are consequently constructing and reproducing the social interaction. Since discourse is part of the social interaction it is culturally dependent.

Healthcare consists of discourses in continuous development, and because of the many divergent discourses, conflicts and misunderstandings may occur. Discourse analysis can help to identify the mechanisms in the social practices, and to interpret discursive structures, social roles, social identities, social behaviour and social practices.There are different approaches to discourse analysis depending on what you want to study. Through *activity analysis* this project focuses on describing the activity type, and on structural, interactional and thematic mapping of the consultations [7] [8]. Activity types are examples of patterns of the communicative situation, and are referred to as a "script" or "form" of the type of activity [9]. An activity type is a description of a communication situation. An activity type can be described by focusing on the following issues: 1) the participants 2) the goals and tasks, 3) the phases, 4) the roles and responsibilities of the participants, and 5) the contextual framework (time, space and artefact) [10] [16]. A *structural mapping* of an activity type includes an identification of communicative markers for defining the focused incident phases. For example, Byrne and Long [11] proposed the following phases in the doctor-patient conversation in primary care: 1) relate to the patient, 2) uncover the cause of the patient's attendance, 3) conduct verbal and / or physical examination of the patient's condition, 4) determine the treatment or more examinations and finally 5) the completion of the consultation. Each of these phases of the consultation can be subdivided into smaller communicative elements. An *interactional mapping* focuses on the communicative relations between the participants in the activity type. Through activity analysis we may reveal aspects of the interaction between the actors in the different phases. Moreover, the *thematic mapping* reveals what issues are at focus in the activity type. This type of analysis may provide both an overview, and the details of what characterizes the discourse and social practice. In this paper, when studying a chain of activity types in a patient trajectory, the focus is on identifying the types of communicative practices and the participants.

III. METHODOLOGY

The discourse analytical approach in this project required an ethnographic and problem-oriented approach. We studied communication in the context in which it normally occurs. To identify relevant empirical data, the researcher conducted a pilot project where she observed selected clinical departments at a hospital in Norway. The purpose of the pilot project was to get an impression of the institutional practices, and the communicative practices at the department. The researcher participated during surgery and clinical encounters, and made field notes. After an overall strategic, technical and practical assessment, the section for vascular surgery was selected as the primary empirical field for data collection of communicative practices in patient trajectories. The cohort consisted of patients with abdominal aorta aneurism (AAA) that would go through either Conventional open (OR) surgery, or an Endovascular Aneurysm Repair (EVAR) surgery [12].

The study is based on participant observation in the empirical field. The researcher followed 10 patients from admission to the hospital, through all the communicative practices that they attended, until they were discharged from the hospital. Exploratory and interpretive methods are useful to promote knowledge of predefined or open research questions [13]. The purpose of this approach is to gain detailed knowledge about what actually happens during health consultations. The researcher has experience with field analysis in general and activity analysis in particular [14]. During the fieldwork and the participatory observation at a large hospital in Norway, the researcher made detailed observation notes and transcripts of the talk of the patients and the healthcare professionals. Additional data was electronic patient records notes and other written material. The purpose of this broad data collection was to gain insights about the whole chain of verbal and written communicative practices between health professionals involved in the treatment of the individual patients.

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IV. RESULTS

This section offers a presentation of the results from the study, focusing on 1) the chain of activity types in a typical patient trajectory for AAA, 2) the participants involved in the different activity types and 3) the communicative practices.

A. *The chain of activity types in a typical patient trajectory*

During the pilot project, and in discussions with the head of the department, the researcher identified the following *chain of activity types* in a typical patient trajectory for patients that are going through AAA surgery:

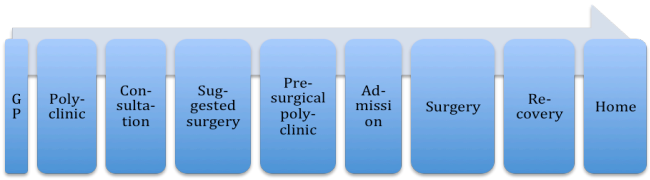

Figure 1. Example of the chain of activity types in a typical patient trajectory for AAA surgery

The patient experiences *symptoms*, and consults the *general practitioner (GP)*. AAA is a condition occasionally without symptoms, and is often identified by chance in other consultations. The GP consults the patient locally, and subsequently refers to a *polyclinic* consultation at the hospital. A consultation with a specialist reveals whether it should be further investigated for possible surgery, or if the patient can be followed up by the GP. The specialist also decides if the patients should be admitted and prepared for Conventional open (OR) surgery, or an Endovascular Aneurysm Repair (EVAR) surgery. The surgical assessment is done at the *pre-surgical polyclinic*, where a nurse, a surgeon, an anaesthesiologist, consults the patient. The surgeon present in the pre-surgical polyclinic ideally also performs the *surgery*. After the surgery is performed, the patient is transferred to the *recovery unit* for observation, and subsequently moved to the *ward* for care. The patients often go through several days of *convalescence* before going home. Throughout the course of the patient trajectory, several communicative practices occur both orally and written, such as the doctor-patient conversations, the professional conversations in one-to-one relationship or team, as well as written referrals, information circulars, notes, patient orientation, discharge summaries, and electronic patient records and health information systems. This identification of the activity types in the ideal patient trajectory was useful in order to understand the complexity of when health communication and information exchange occurs during the patient trajectory. However, as we shall see in the subsequent section, the chain of activity types is even more complex.

The fieldwork of this study starts when the patient presents at the hospital for a pre-surgical polyclinic consultation. The patient trajectories of OR surgery differ from those during an EVAR surgery, due to differences in *participant structure* and *types of communicative practices*.

a) *Participants in the different activity types*

The participant structure [15] refers to how the organization of interaction in large group work, small group work, pair work or individual work. The distinction is relevant for how we evaluate the social interaction and the distribution of verbal contributions during the activity. One activity type, for example the surgical intervention, would have different participants and thus another participant structure than other activity types, for example the consultation between the doctor and the patient. The accepted norms, roles and verbal contributions are related to the participant structure. An identification of the participant structure in the respective activity types requires an identification of the participants in the activity types.

The observation of the OR versus EVAR-patients showed several participants in each of the phases of the patient trajectory respectively pre-surgery, surgery and post-surgery.

Pre-surgery

TABLE I PARTICIPANTS IN THE PRE-SURGERY PHASE

Basic activity types and participants	**Participants basic activity types**	**Additional crew for OR**	**Additional crew for EVAR**	**Additional partici-pants**
Admission meeting and instructions	Patient and Nurse 1	Physio-therapist	Radiological pre-procedure planning team	Nursing student Doctor student
Bloodtest	Patient and Nurse 2			
Information meeting about surgical procedure	Patient and Surgeon			
Information and examination about medication	Patient and Anesthesiologist			

The basic crew in the pre-surgical activity types for both types of surgery includes: *a coordinating nurse* who receives the patient in the vascular surgery ward, and who forwards him to the blood test department, where he communicates with the *blood test nurse*. When the patient returns to the ward, he is called in for consultations with respectively a nurse (who takes personal information notes for the record), a *surgeon* who explains briefly what will happen during surgery and an *anaesthesiologist* (who considers allergies, medicines and explains about the aesthetic procedure.) The pre-surgery activity types for the

OR surgery include the physiotherapist, while the pre-surgery activity types specific for the *EVAR surgery* may include a consultation with the radiologist.

Additional professionals in the pre-surgery activity types are the students training to be doctors or nurses. All these activity types include different kinds of communicative practices, such as talk, reading electronic patient record, writing in electronic patient record and occasionally also referring to medical imaging or simple drawings to illustrate the medical condition.

Surgery

The participants present during *surgery* differ between the OR and the EVAR.

TABLE II PARTICIPANTS DURING SURGERY

Basic activity types and participants	**Participants basic activity types**	**Additional crew for OR**	**Additional crew for EVAR**	**Additional participants**
Surgical activity	Patient Anesthesiologist Anesthesiology nurse 2 Vascular surgeons 4 Operation nurses		Interventional radiologist Radiology nurses (two)	Doctor student 1 Doctor student 2

In addition to the basic crew, the EVAR surgery involves a radiologist and two radiologist nurses. The surgery activity type is a complex interdisciplinary team communication, and a large number of communicative practices are involved, such as talk across professional boundaries, reading and writing diagnostic information and observations in different databases (according to the professional task, for example the anaesthesiologist registers in one database, whereas the surgeon registers in another and the nurses in the third database).

Post-surgery

TABLE III PARTICIPANTS IN THE POST-SURGERY PHASE.

Basic activity types and participants	**Participants basic activity types**	**Additional crew for OR**	**Additional crew for EVAR**	**Additional participants**
Transfer of patient from operation room to intensive care	Operation nurses (same as during surgery)	Physiotherapist		Nurse student
Intensive care	patient and nurses			
Intensive care	patient and doctor			
Recovery	patient and nurses			
Recovery	patient and doctor			
Surveillance	patient and nurse 1			
Surveillance	Patient and nurse 2			
Ward	patient and nurses			
Ward	patient and doctors			

The post-surgery crew concerned with the patient after the OR consist of several health care professionals, both in the intensive care unit, the recovery unit and in the ward. Since the patient usually is in the ward for several days post-surgery, he experiences the change of guards as the surveillance crew and the ward crew change 3 times in 24 hours.

Table 2, 3 and 4 illustrate that the chain of activity types is actually more complex than identified in the pilot project (see section A), and that a large number of healthcare professionals are involved during both the OR and the EVAR patient trajectories.

b) Identifying communicative practices

The communicative practices referred to here are the different types of interactional activities, be they verbal or written that concern the patients.

The communicative practices have different characteristics: 1) where the patient is explicitly involved, 2) between healthcare professionals within the department 3) healthcare professionals within the department and "satellite professionals", such as the anaesthesiologist, the physiotherapist, etc., and 4) healthcare professionals across departments (surgery, recovery, and ward).

Pre-surgery

Based on our observations, we have identified numerous communicative practices in pre surgery.

TABLE IV COMMUNICATIVE PRACTICES PRE-SURGERY

Communicative practice including patient	**Communicative practice between professionals in the same department**	**Communicative practices with "satellite professionals"**	**Communicative practices with other departments or organizations**
Admission meeting and instructions, Patient and Nurse 1, talk and writing nursing summary	ICT-based written information exchange through different systems and written paper record Inter-professional meetings	Nurse-physiotherapist talk Surgeon-anesthesiologist talk Surgeon-radiologist talk	ICT-based written information exchange through different systems (Doculive, Picis, operation planner)
Blood test, Patient and Nurse 2, talk			
Information meeting about surgical procedure, Patient and Surgeon, talk and drawing			
Information and examination about medication, Patient and Anesthesiologist, talk and medication list			

In the pre surgery phase, numerous communicative practices take place concerning the patient. The patient is involved in consultations, and will be able to influence the communication, through questions and information. Moreover, there are communicative practices where the patient is not involved, and where information is exchanged, discussed and decisions are being made about the patient.

TABLE V COMMUNICATIVE PRACTICES DURING SURGERY

Communicative practice including patient	**Communicative practice between professionals in the same department**	**Communicative practices with "satellite professionals"**	**Communicative practices with other departments or organizations**
Patient -nurse 1,2,3 talk Patient - surgeon 1 and 2 talk Patient-anesthesiologist talk etc.	Surgical checklist, interprofessional team-communication during surgery, use of visualization technologies,	Surgeon-surgeon 2 talk Surgeon- nurse 1,2,3 talk Surgeon-radiologist Surgeon-anesthesiologist talk etc.	ICT-based written information exchange through different systems (Doculive, Picis, operation planner)

During surgery of OR, the patient receives full anesthesia. He is unconscious, and is only involved in talk before going into anesthesia and after wakening post-surgery. Contrarily, during EVAR, the anesthetic is local, and the patient is involved in talk. The nurses, surgeons and radiologists can communicate with the patient, and the patient is an eavesdropper to the professional talk.

TABLE VI COMMUNICATIVE PRACTICES POST-SURGERY

Communicative practice including patient	**Communicative practice between professionals in the same department**	**Communicative practices with "satellite professionals"**	**Communicative practices with other departments or organizations**
Patient-intensive care nurses talk Patient-intensive care doctors talk Patient-recovery nurses talk Patient- ward nurses talk Patient-physiotherapist talk		ICT-based written information exchange through different systems (Doculive, Picis), team discussions	ICT-based information exchange through different systems (Doculive, Picis), nurse summary, clinical notes/patient summary, discharge letter, medication list etc

In the post-surgery phase, the patients that have undergone OR wake up, and are immediately drawn into communication with the anesthetics doctors and nurses for them to check his state of consciousness. In the intensive care, the patients are tired, but are still approached communicatively by the nurses, the surgeon and the intensive care doctor with information about the operation. Reports where given from patients that did not understand any of the communication in the intensive care due to drowsiness.

Table 5, 6 and 7 give an indication of the communicative practices in the respective patient trajectories. There is a large number of communicative practices during the trajectory, be they verbal practices (talk) of written practices (ICT or paper based), each with different characteristics.

V. DISCUSSION

The identification of the *chain of activity types* in a typical patient trajectory enables us to get an overview of all the activities that concern the patient during his stay at the hospital. In this paper we saw that a patient trajectory in AAA from identification of symptoms (Figure 1) only gives a very general overview of the activities that will concern the patient that has to go through the surgery. A narrow look at the activity types taking place at the hospital between admission and discharge from the hospital, illustrates that the patient takes part in many activities, with a lot of participants with different tasks who are communicating in different ways and with the use of different tools.

The identification of the *participants* in the different activity types gives an idea of the social organisation, work tasks, norms and roles in the activity types while the identification of the *communicative practices* in the activity types helps us to pinpoint how information is transferred from one participant to the next in the trajectory. Information is likely to be missed and misunderstood during such a chain of complex communicative practices. In addition, the complexity of participants and communicative practises is likely to influence the patient's possibility for informed decision making, as she has not access to all information. The mapping of the complexity of health communication and information exchange in the patient trajectory suggests that patient involvement and decision making, as emphasised in the user centred perspective, and manifested by the for example the slogan *No decision about me, without me*!, may be difficult to obtain.

Identifying these three structural elements (activity type, participants and communicative practices) in actual patient trajectories can be useful both from a patient centred-, a clinical- and an administrative perspective.

In general, the identification of these elements is useful for pinpointing where and when communicative challenges may and do occur between patients and healthcare professionals or between healthcare professionals of different disciplines. From an administrative level, an identification of activity types, participants and communicative practices are tools for making the trajectory more efficient.

Once the structural elements are identified, we can study the activity more closely, by analysing how and what the participants are communicating about. In the two following papers, the focus will be on respectively interactional mapping and thematic mapping of selected activity types in the AAA patient trajectory.

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Emerging Issues in Medical and Engineering Ethics: The Case of Reverse Paternalism in Lebanon

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***Abstract*— There are different occupations and professions in almost every society, and despite all the ethical frameworks that govern professions by professional ethics, it is widely noticed that there are still challenges facing each profession. One of those ethical challenges is related to paternalism. Paternalism is the act of interfering with a person's autonomy by making decisions for them claiming that it is "for their own good". In a developing country like Lebanon, an ethical dilemma is commonly noticed in the field of medicine but not commonly discussed in the literature. This dilemma will be termed and defined for the first time as reverse paternalism. Reverse paternalism refers to the act of sacrificing one's autonomy and self-determination and giving another person or group the right for making decisions on their behalf. People are considered moral agents and some are giving up their autonomy and rights for making decisions to medical practitioners because "they know better". The main focus of this paper is therefore on reverse paternalism that will be investigated as an ethical dilemma being faced in Lebanon. What exactly is reverse paternalism? Are there regulations that restrict such kind of paternalism? How do medical practitioners act in such situations? And to what extent is there auditing over what happens in hospitals, private clinics, medical centers and institutions? Our aim is to shed the light on this ethical dilemma and highlight how serious and wide spread it has become, by providing statistical data we have collected. We will also provide recommendations based on cases showing the adverse ramifications of reverse paternalism on society.**

Keywords—medical ethics; *engineering ethics; medicine; paternalism; reverse paternalism*.

I. INTRODUCTION

We live in a world that is divided into groups of distinct fields related to disciplines of different schools. People get education and major in different fields to become professionals and enter the world of employment. Doctors, scientists, professors, lawyers, teachers, engineers, etc., find themselves in situations where important decisions have to be made, and because they are the ones "who know better", their decisions have to be right, especially when other people depend on them. Governmental morals are often incomplete without personal morals. Three types of moralities or ethics have arisen, namely, common morality, personal morality, and professional ethics [1]. Each country classifies various occupations as being a profession or not. Engineering for example is considered a profession in our society and therefore needs a set of standards to be adopted by professionals. Each profession should include a basic methodology for deciding what is morally right and what is morally wrong in one's professional conduct to qualify whether an action is right or wrong. This normative ethics and principles leads to the codes of ethics that demonstrate the accountabilities and duties of each profession and when these codes are followed, the field flourishes and brings changes to the field and the world as well. But what happens if these codes are not taken into consideration and professionals act outside the ethical frameworks that govern their behavior? And who is affected by such unethical acts?

Despite of all these normative ethics and standards, it is widely noticed that there are still challenges facing each profession. As Biomedical Engineers, one of the professional obligations that governs our personal practice is to regard responsibility toward the rights and the health of patients and since the doctor-patient relationship is an example of a relationship between individuals which is ruled by ethical behavior, we found that it is important to shed light on one of the ethical challenges that faces this

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relationship which is the long-practiced *paternalism*. Paternalism is the act of interfering with a person's autonomy by making decisions for them claiming that it is "for their own good" [2].

Paternalism is problematic because the definition of a patient's best interests used by a paternalistic approach is too narrow, because such best interests should not be determined by the medical facts alone but the patient's views and judgments should be taken into consideration also. It has become evident that doctors often act in a paternalistic way about their patients claiming to do so because they "know better". In a developing country like Lebanon, various medical practices lack a successful shared decision-making because of the physicians' attitudes and irresponsibility on one hand and the patients' lack of education, fear, laziness and the inability to make a serious decision on the other hand. But what is really interesting that paternalism nowadays is encouraged by the patients themselves; in other words, paternalism is being reversed and moral agents, such as patients, customers etc. are giving up their autonomy either intentionally or unintentionally. This ethical dilemma is commonly noticed in the field of medicine, and will be termed and defined for the first time as reverse paternalism. This paper will provide a small background about ethics, and discuss paternalism and the possible causes of reverse paternalism. Patients were surveyed with a questionnaire designed to identify the extent of reverse paternalism tendencies. Hence, a definition and some possible solutions will be proposed. Medical reverse paternalism is one of the ethical cases that specifically apply to biomedical engineering, but all types of engineering in general as well. This is the first time that this ethical issue is being identified, quantified, discussed and assigned of being a real problem and factor in various fields such as medical diagnosis and treatment in Lebanon. Our aim is not only to gather data of the extent of reverse paternalism in Lebanon, but also try to understand how to raise the awareness of patients for their treatment choice rights. This is implemented by distributing a questionnaire with very direct questions related to reverse paternalism.

In Section II, we will define ethics and their contributions to religion and culture, to give an idea about the influence of religious and cultural ethical aspects on decision-making processes of people. In Section III, ethics will be explained and defined according to their types in the fields of bioethics, engineering ethics and medical ethics, as well as biomedical engineering ethics. Section IV will be about the scope of this paper, which is reverse paternalism. In this section, the link between paternalism and reverse paternalism will be explained. It will also be defined for the first time given a title and explanation of the importance of engineers contributing to this dilemma. It will also highlight the relation between biomedical engineers and ethical dilemmas that are found in medical practices, and the importance of taking responsibility for what happens with patients in medical practices. Section V is an explanation of the concept of informed consent that is obligatory in medical practices for patients to know what exactly will be done during certain treatments. Section VI provides a clear explanation of how a decision-making process between patients and doctors should be done, in addition to a comparison to how it is done in Lebanon, in our observation. Section VII includes the survey that was done by distributing a questionnaire and collecting data, in addition to a presentation of the results of our investigation. Finally, Section VIII is a conclusion of what we have hypothesized and the outcome of whether reverse paternalism is an ethical challenge in Lebanon or not.

II. WHERE IS ETHICS FOUND?

Ethics is a group of principles, values, rules and regulations, beliefs, morals and rules of conduct [1]. This group organizes goals and actions for the achievement of the most important values one can have. This means that any flaw in behavior might mislead one from the path of being ethical. Ethics can be described as being a system of moral principles that differentiate between what is right and what is wrong. In other words, ethics is a norm of conduct that recommends concepts of acceptable and unacceptable behavior.

All cultures have systems of health beliefs to explain what might be the cause of a certain illness, the way it can be treated and who will be involved in it. Culture specific values have high influence on patient roles and expectations. It often specifies how much information is desired, how death/dying will be managed, sorrow patterns, gender family roles, and processes for decision-making [3]. Therefore, each culture brings its own views and values to the healthcare system which alters healthcare beliefs, health practices, and of course the nature of the doctor-patient relationship. Cultures differ mainly between developed and under-developed countries. Developed countries adopt a shared decision-making process between the patient and the doctor, where the patient receives all the information, support and education that is needed and asked for by the patient. Whereas developing countries rather lack that kind of relationship and consultations between patients and their doctors.

Ethics can be seen as the base of religions, though it is explained and may be even seen from different perspectives in various religions. Since religion has very high impact on how most of the people live, behave and how they do not behave, then ethics must be applied to tell whether this act is right or wrong. However, each religion has another opinion of how to clarify ethical principles. Lebanon is known to have the most religiously diverse society in the Middle East, hence it is important to address the issue of Reverse Paternalism from a religious point of view. By approaching this case, Christianity and Islam will be considered rather generally. We find that Western Christian Civilization, and specifically American medicine, is founded upon Biblical

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ethics and the tradition of the Greco-Roman Heritage. These are based on several principles such as the presence of moral codes and moral justifications, the doctor-patient relationship, in addition to moral integrity etc. Life in all its forms has a very high status in Islam, and human life is one of the most sacred creatures of God. It must therefore be respected, appreciated and protected. Islamic law is called the Shari'a and is not the same as Islamic ethics, since in Islam everything has to be checked twice, first if it is against legal standards and second against moral standards [4]. There is an absolute harmony between Islamic law and morality, but they have still different objectives, meaning that they might differ in their prescriptions.

III. THE MAIN TYPES OF ETHICS

Our study mainly concerns ethics in biomedical engineering, which is the intersection between bioethics, medical ethics, and engineering ethics. In order to understand the relationship and contributions of these fields with one another a brief overview of each is provided.

A. Bioethics, Medical Ethics, and Engineering Ethics

Bioethics is an activity; it is a shared, reflective examination of ethical issues in health care, health science, and health policy [5]. It defines the basic ethical values for the conduct of biomedical and behavioral research involving human and non-human subjects.

Medical ethics is a system of morals and principles being applied to situations that are specific to the medical world and the practice of medicine. Ethical principles are mainly: autonomy, beneficence, justice and non-maleficence [6].

Engineering ethics stands for the set of ethical standards and principles ruling the behavior of engineers in their title role as professionals. In other words, an engineer should be devoted to the protection of public health, safety, and well-being [1].

B. Biomedical Engineering Ethics

Biomedical engineering is the application of engineering principles and techniques to medicine and biology. Each profession is ought to include a basic methodology for deciding what is morally right and what is morally wrong in one's professional conduct. Ethics is considered to be the central concept to biomedical engineers, since its principles guide them to recognize ethical problems and attempt to solve them. This is why there is a code of ethics that emphasize the major principles of a biomedical engineer being followed and respected. But what is a principle?

A principle is used as a basis for ethical reasoning by guiding a specific action or behavior. Autonomy, Beneficence, Non-maleficence, and justice are the main principles biomedical engineering ethics is based on [6].

IV. REVERSING THE TIDE OF MEDICAL PATERNALISM

Every time the state of a person is interfered with another person's autonomy, it is a case of paternalism, which of course is claimed to be of benefit for the person who "knows less" than the one acting paternalistic. This act is often justified and thereby wrapped in a more attractive appearance as providing protection and hence the best for the other person. A significant kind of autonomy is the one that exists as a counterweight to the medical profession's long-practiced paternalism. Today, the principle of patient autonomy and self-determination has emerged as the dominant ethos in health care, threatening in many instances to totally eclipse the principle of medical beneficence [7]. The typical doctor-patient relationship, where the physician acts paternalistically towards their patient and takes decisions for them and very often not even explains why and how the decision was taken. In their opinion, there is no need to explain, because the patient either would not understand it, or does not need to know about it. There are many reasons that may have led to this situation that we find in these days, especially in Lebanon.

What makes it such a serious and dangerous case is that patients do not even notice how they are being used and are losing their autonomy because a doctor just decided that this pregnant woman cannot give birth naturally and needs to undergo a caesarean operation instead. This woman of course believes it because in the end she thinks that her doctor is just doing what is right and best for her and her baby and this is all she cares about. But what this woman does not know is that very often it is not her that benefits from this operation, but her doctor. It is a common knowledge in Lebanon that there are many doctors that can be considered more as businessmen rather than physicians that once took the Hippocratic oath. What matters is how much they benefit instead of acting according to the principles that seek for beneficence, non-maleficence, and justice for the patients.

Because people behave according to their culture and religion, a doctor should at least be aware of what those tell the patient to do. Is mere knowledge enough to justify the limitations that patients are subjected to on their liberty or violations of their autonomy? And is it even morally defensible to act paternalistically in the sake of preventing harm and providing welfare and benefit? At first thought one might think of course it is, but the real problem that is addressed here is that such acts are done without taking the patient's opinion into consideration, neither does the doctor explain what might be the side effects of certain decisions.

People can be paternalistic. Institutes can be paternalistic. Motivations can be paternalistic. Acts can be paternalistic. Reasons can be reasons of paternalism. Paternalism is found everywhere. But does this completely incapacitate our ability to make our decisions and choices? Does giving up our right to choose become a habit? The real problem exists when people, in particular patients,

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proactively give up their autonomy by themselves and leave all the decisions to the physician, again, because "they know better". Many of those may be too old to take certain decisions, and others might just not understand what will happen thereby, diminishing their rights to choose. Whenever a patient asks his/her doctor to prescribe whatever medicine or medical intervention that the doctor sees fit, we have a case of Reverse Paternalism. Whenever a patient refuses to choose a treatment procedure among other procedures and trusts the doctor to choose for him, we have a case of Reverse Paternalism. Whenever a patient is advised to perform a medical image in a specific laboratory assigned by a doctor and does not question the doctor's recommendation, we have a case of Reverse Paternalism. Therefore, these acts feed the tide of paternalism to give rise to an emerging ethical dilemma termed as Reverse Paternalism, which is the act of sacrificing one's autonomy and self-determination and giving another person or group the right for making decisions for them. The patient allows the physician to do what is best for them, and this way taking life-based decisions for them. What this patient might not have thought about is that this doctor might misdiagnose a case and make mistakes. Who is to blame in such cases? How honest is this doctor and to what extent might he/she be saying the truth?

There are numerous reasons that push patients into giving up their autonomy and let their physician choose for them. Though most of these reasons neither justify nor solve the dilemma of reverse paternalism. Yes, there are many cases one could think of where reverse paternalism is the right thing to do, but there will never be certainty to that the physician's interest is only their patient and their health. So, to what extent can doctors be trusted?

The least this patient can ask for is information. There is a whole protocol to be followed if a patient must undergo a surgery. The physician is ought to take enough time in order to explain why the surgery has to be done, who will be doing it, where is it going to happen, what the consequences and side-effects might be, if there are other choices, and what might happen if this surgery was not performed. Images and explanations with simple terminology should be used in order to make sure that the patient has understood everything and can now decide and choose. This patient must be a moral agent and the physician must try as much as possible not to act paternalistically and abide by the rules of professional medicine. Paternalism induces power imbalance between health professionals and patients. The professional should be the expert in the area of diagnostic information, treatment options and possibilities. But the patient is also an equally valid expert, with specialist knowledge in her or his own personal concerns, history, family roots, philosophy and way of life. The expertise that the professional brings to the consultation is not merely technical [8]. This kind of paternalism is most commonly present in the field of medicine, and directly related to biomedical engineering in particular, and engineering in general.

As Biomedical engineers, it is our obligation to conduct responsibility towards the rights and safety of patients that are part of this issue. For this reason, we find it important to shed light on this challenge of reverse paternalism, and inform people about the importance of remaining their moral agency. It is important to find out how frequent a successful shared decision-making process is in a developing country like Lebanon, in order to investigate the reasons behind this ethical dilemma. This dilemma interferes with decisions taken by engineers who work in the medical field. Biomedical engineers are engaged in a range of interactions, which includes interactions with patients as well as doctors. We noticed in our society that there is a clinical dependence of patients in their decision-making process on the opinions of their doctors. Some patients tend to trust their doctors to an extent that made the doctor-patient relationship crossing the boundary of professional ethics.

Biomedical engineers are responsible agents in their respective profession, which means that they must act in the interest of the patients and use their knowledge and skills to benefit them and inform and alert them when it is needed. Because biomedical engineers are engaged to deal with medical devices and equipment in hospitals and health care facilities, then they have responsibilities towards the life and safety of patients. One example that reveals the issue is when a doctor prescribes MRI or CT scan at a specified medical laboratory for a patient for no clinical reason, only for the benefit of the doctor or to benefit the medical laboratory and the patient accepts and trusts their doctor and allows them to make decisions on his/her behalf. Here, the biomedical engineer can either accept that kind of behavior and even make use of the patient's dependence and ignorance, or encourage legislations regarding this issue and educate the patients and alert them about the hazards of

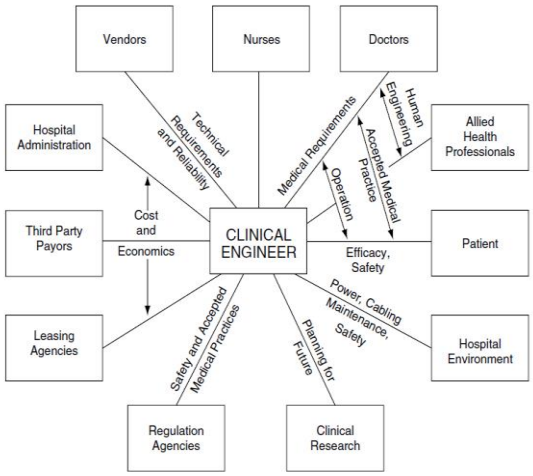

Figure 1. Diagram Illustration of the interaction of a Clinical/Biomedical engineer [9].

radiations and the technical implications of any medical procedure/treatment and strive to protect the patients and their rights and educate them about the importance of getting involved about decisions regarding their treatment.

As engineers, we are expected to satisfy the standard of care by holding paramount the safety and health of the public. As biomedical engineers, we must act in patient-centered manners and apply engineering principles in managing medical systems and devices in the patient setting. Thereby, we are obliged to regard responsibility towards the health and safety of patients. Figure 1 illustrates the interaction between a clinical/biomedical engineer and other parties. This not only verifies that a biomedical engineer is involved in all decision-making processes with all kinds of departments, in any healthcare facility, but it also highlights the fact that patients are prioritized. Our role as biomedical engineers is patient-centered and this is another reason for us to approach this ethical dilemma with high interest. The current patient-doctor relationship that is presented in our society has triggered our sense of responsibility; where we identified an emerging ethical dilemma concerning this relationship where we think that some patients themselves are encouraging the act of medical paternalism, which is long practiced by doctors in the medical field.

V. INFORMED CONSENTS IN MEDICINE AND ENGINEERING

Let us take a closer look at this principle and explain its importance. As mentioned previously, moral agents have the autonomy to make decisions on their own, and differentiate between right and wrong. A patient has therefore the capacity to act intentionally with a full understanding, and without influence of a free and voluntary act. It is the basis for the practice of an "Informed Consent". It is very important to shed light on what an informed consent is because it has become evident that many people do not even know of its existence. An informed consent is a process for getting a patient's permission before being subjected to a certain healthcare intervention. In other words, when a patient is diagnosed to undergo a surgery or receive therapy, the physician is obliged to get the patient's permission. This is done by providing them with a document that contains all the information the patient has to know before taking the decision of permission or not. It comprises a clear appreciation and understanding of all the relevant facts, implications, and consequences of the specific therapy or surgery. Certainly, no information should be kept from the patient so that they are able to form a rational decision and to avoid severe ethical issues arising from the lack of sufficient data. If a patient is not able to take any decision due to mental disability, sleep deprivation, Alzheimer's disease, or being in a coma, or immaturity, then another individual is certified to give consent on their behalf such as parents, siblings, or legal guardians of a child.

Sometimes the consent is divided into an information component, and a consent component. The information component refers to disclosure of information and comprehension of what is disclosed giving the patient the chance to consider its content in his/her decision-making. The consent component refers to both that his decision is a voluntary decision and that permission is given to proceed. Note that informed is collected according to guidelines from the fields of medical ethics and research ethics.

In Lebanon, many patients that have undergone surgeries or treatments, sound surprised when hearing the word "informed consent", which implies that they most probably have never seen one and thereby permission was taken only orally if not paternalistically. The informed consent is not only a must for patients, but also a protection for physicians. It is evidence that the patient agrees to what will happen to them, and what might happen if they did not undergo this surgery or therapy. Not only has the patient the right for an informed consent, but also the physicians and doctors. Many practitioners believe however that patients may thus be better served if efforts are directed instead to finding ways of minimizing hard paternalism without too great a compromise on patient's freedom [7]. This argument is yet to be validated from an ethical perspective.

VI. DECISION-MAKING PROCESS

Decision-making process is the process of selecting a belief or a course of action among various alternative choices. Taking the doctor-patient relationship as an example to illustrate this process, seven main steps will be explained in order to highlight the importance of the informed consent that is part of this process [10]:

1) *Identify decision to be made*
2) *Gather relevant information*
3) *Identify alternatives*
4) *Weigh evidence*
5) *Choose among alternatives*
6) *Take action*
7) *Review decision and consequences*

Doctors have the medical knowledge that makes them superior to patients in decision-making. They do know best in the sense that they have more scientific and medical information concerning injuries and diseases and their elimination and elevation more that the patients have. Therefore, patients are advised to surrender to this epistemic authority. This issue raises various ethical and social questions that should be taken into account. There are many patients that do want to know and gain knowledge about their diagnosis or treatment, but the main challenge is about the patients that show no interest to shared decision making. Patients are now quite aware of how the process of decision-making is done. Table I illustrates a comparison between

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how decision-making should occur, and how it is done here in Lebanon. When describing what happens in Lebanon, only a general idea of what is happening is given, showing why it is so important to find solutions and recommendations for encouraging patients to follow a process of shared-decision making. However, reasons are numerous, and most of them might be of cultural sources. There is a strong relationship of dominance and affection between decision-making and culture. Just like ethics in general has an impact on religion or cultures, these cultures have an impact on how patients might take their decisions. Patient roles and expectations are often influenced by culture values, sometimes it is influenced by how much information and about illness and treatment is desired, how death and dying will be managed, sorrow patterns, gender and family roles, and hence processes for decision making. Each culture brings its own views and values to the health care system, which alters health care beliefs, health practices and doctor-patient relationship. A general guideline for such relationship should be based on an approach of mutual respect and appreciation of roles. Just as professionals must not abuse their position by manipulating or coercing patients against their will, so patients must not coerce professionals to go against their fundamental ethical convictions and professional values [8].

VII. SURVEY

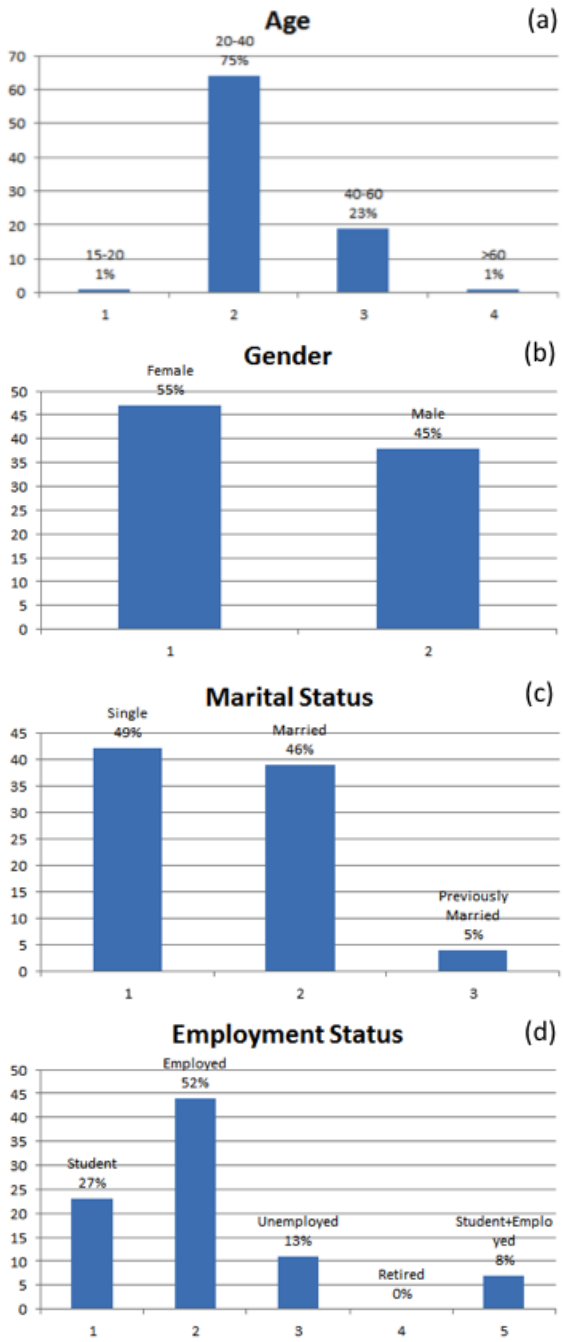
The purpose of this survey is to examine the presence of the suggested phenomenon in Lebanon and to assess to what extent it is present in the field of medicine. If the results indicate that this phenomenon is spread in our society, then we must alert people about it and we must try to suggest some regulations to restrict such kind of paternalism.

The following hypothesis is formulated to achieve the objectives of the present study: A new kind of paternalism is emerging in the field of medicine in Lebanon, termed as Reverse Paternalism.

The study was conducted on a representative sample of 85 patients in Beirut region. The patients who were selected in the sample were males and females with diversity in age and education. (Table II represents a sample of the questionnaire). The questionnaire consists of 20 items and each item has five alternative responses: strongly disagree, disagree, neutral, agree, and strongly agree. These items are related to the following concepts:

1. Patient's autonomy
2. Decision making process

The questionnaire has a variety of questions that refer to a paradigm of reverse paternalism or the absence of reverse paternalism, as well as a neutral point of view. Figures 2-a, b, c, and d give an illustration of the age, gender, marital status, employment status, and educational level. A total of



Figures 2. a, b, c, and d show the personal information of surveyed patients who answered the questionnaire.

85 patients have answered 20 questions. Each question was analyzed in order to categorize it. Questions 1, 4, 6, 7, 8, 10, 12, and 15 are direct questions referring to reverse paternalism. The questions can be separated as two types, 10 positive questions and 10 inversed questions meaning the opposite of the positive ones. As Figure 3 shows, 85% ask their doctors about information about suggested treatments or procedures. 70% disagree with their doctors not involving

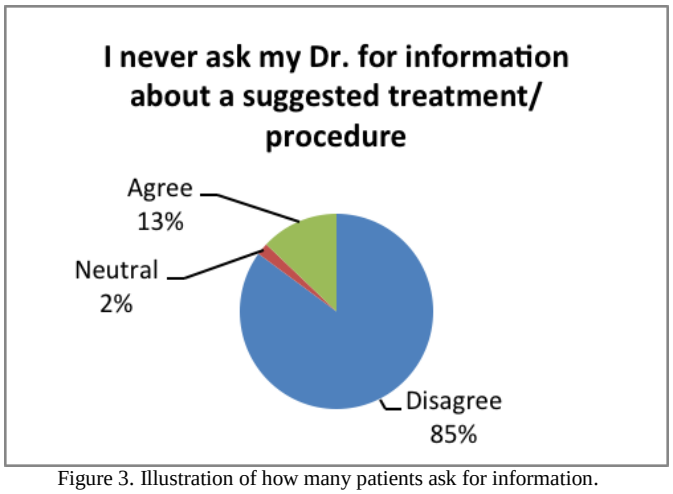


Figure 3. Illustration of how many patients ask for information.

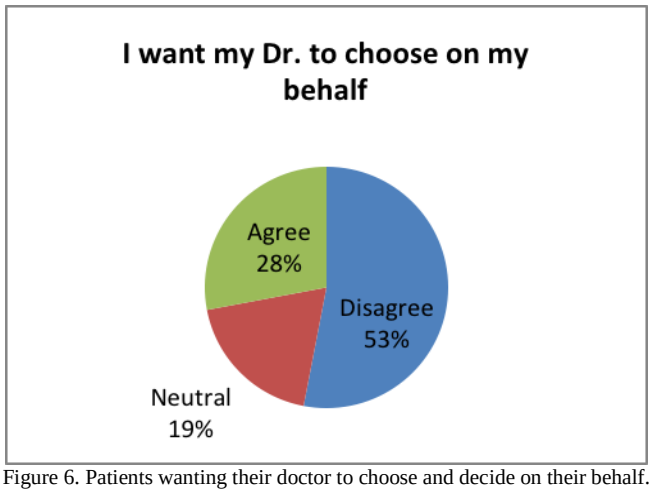


Figure 6. Patients wanting their doctor to choose and decide on their behalf.

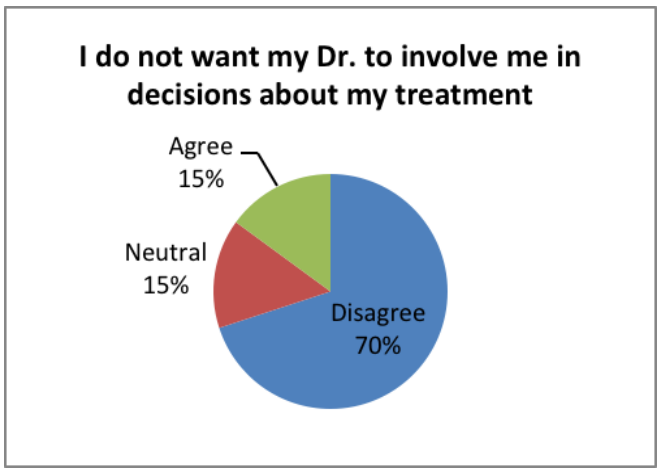


Figure 4. Patients' disagreement on not being involved in decision-making processes.

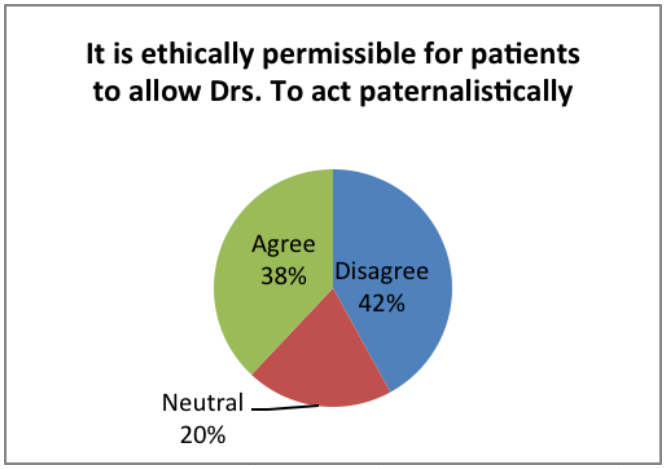


Figure 7. The percentage of patients who find it ethically permissible for doctors to act paternalistically.

Figure 5. Patients say that they have a successful shared-decision making process with their doctors.

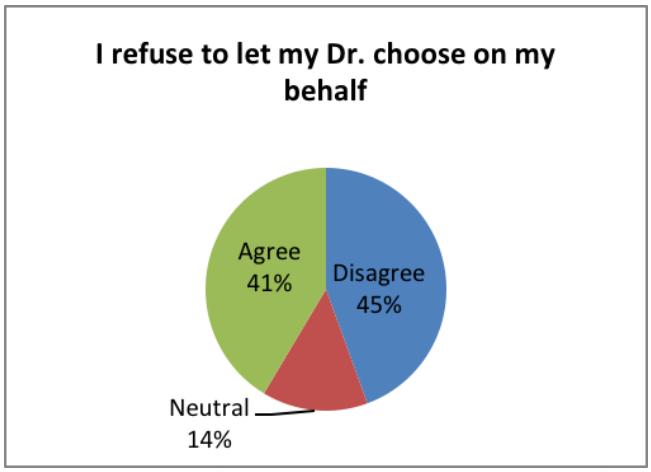


Figure 8. Patients refuse to let their doctors choose on their behalf.

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them in decisions about their treatments (Figure 4). Only 53% do not allow their doctors to choose on their behalf, 19% have a neutral opinion, which means that 28% allow their doctors to take decisions for them (Figure 5). Figure 6 illustrates how 38% agree that it is ethically permissible for doctors to act paternalistically with their patients. When asked if they refuse to let their doctors to take decisions on their behalf, 44% disagreed (Figure 7).

As most of the results indicate the existence of weak reverse paternalism, we took a closer look at the age and educational status of those who showed tendency towards reverse paternalism. Some of the patients that are in the age range of 40-60 years have a lower educational level, due to the complications of war Lebanon has faced, also showing tendency towards reversing paternalism. We chose a patient to ask about his last visit to a Doctor. This patient was a married, employed male of age between 40-60 years of age with an elementary educational level. He was asked about how much he trusts his Doctor and how much he believes in what he prescribes as treatments. He agreed on telling us what his problem was and what was prescribed, and when we asked him if he knows what each drug is for he said no and responded: " He is a very good Doctor and I am sure he knows what is best for me and what to prescribe for me to get better." Again, we took a closer look at the questionnaire this patient had filled, and noticed that they do not quite match the way he really acted.

VIII. CONCLUSION

Who is to blame? When patients give up their autonomy in the thought of having someone more educated and professional taking decisions for them? Who is to blame if that person did not do what is most beneficial for the patient? Reverse paternalism appear to be a serious issue in developing countries. However, it has not been defined yet because people have not acknowledged it till now, even though it has become a common knowledge in the medical practice. This is due to the absence of the regulations specific to reverse paternalism that can restrict the physicians' unethical behavior towards patients. Physicians who are supposed to be committed to the Oath they made are making use of some patients' dependence and lack of education for their own interests, with the absence of ethical concepts or regulations. In Lebanon, medical practitioners lack the sense of responsibility due to the lack of auditing and supervision over what happens in hospitals/clinics.

A good test for their responsibility is the question "Do physicians commit to ethical or legal standards when there is no supervision?" and it seems that most doctors fail this test!

Our intentions were not only to get numbers and percentages of people who really are reversing paternalism or not, but as mentioned previously in the introduction, the questions were direct on purpose. Some of the questions were answered as how patients should act, but do not really act like in real life. This does not mean that the results are far from reality, because patients were very honest, but it rose awareness and may even prevent patients from not only reversing paternalism, but also reduce the long-term practiced paternalism. Now, surveyed patients may think twice about how to undergo the process of shared-decision making. As engineers, it is our responsibility to alert people, inform them about problems and challenges they might face and advise in order to help them avoid harm. Since numbers are still not very high, reverse paternalism might be just at its beginning to increase, and our aim is to reduce and prevent this ethical issue from happening.

Recommendations must be provided to control this ethical dilemma. Ethical guidance that governs the behavior of doctors and patients in cases of Reverse Paternalism should be developed. Highlighting the importance of consent before any medical intervention is another recommendation. Moreover, we recommend organizing at least one meeting before any operation where the patient consults and gets all the information needed. In order to raise that issue and let people know that they do not have to give up their right of autonomy, medical practitioners should teach people to ask!

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TABLE I. THE DECISION MAKING PROCESS.

Process steps	Description of each step	Application of each step in Lebanon
Identify decision to be made	Go through an internal process of trying to define clearly the nature of the decision you must make.	Patients realize that there is a decision to be made but instead of going through an internal process, they immediately ask their physicians for advices and what to do.
Gather relevant information	Most decisions require collecting pertinent information. The real trick in this step is to know what information is needed the best sources of this information, and how to go about getting it. Some information must be sought from within you through a process of self-assessment; other information must be sought from outside yourself-from books, people, and a variety of other sources. This step, therefore, involves both internal and external "work".	Many people do now know where to look for information or whom to ask. Others try to get information from people with similar experiences instead of researching properly. The process of self-assessment is sometimes not clear to certain patients.
Identify alternatives	Through the process of collecting information you will probably identify several possible paths of action, or alternatives. You may also use your imagination and information to construct new alternatives. In this step of the decision-making process, you will list all possible and desirable alternatives.	Many patients ask their physicians for alternatives, but do not know where to look for information other than their healthcare practitioners, which is the same problem found in step 2.
Weigh evidence	You draw on your information and emotions to imagine what it would be like if you carried out each of the alternatives to the end. You must evaluate whether the need identified in Step 1 would be helped or solved through the use of each alternative. In going through this difficult internal process, you begin to favor certain alternatives, which appear to have higher potential for reaching your goal. Eventually you are able to place the alternatives in priority order, based upon your own value system.	The challenge in this step is that many patients do not even reach this step. But helping them reach this point would make it easier for them to be able to imagine themselves in certain situations.
Choose among alternatives	Once you have weighed all the evidence, you are ready to select the alternative, which seems to be best suited to you. You may even choose a combination of alternatives.	What is done here, is that most patients only take into account the alternatives their physicians have told them, so when left with a number of alternatives they are lost when confronting decisions on their own. (Only if physicians haven't been paternalistic when implying what alternative to choose).
Take action	You now take some positive action, which begins to implement the alternative you chose in Step 5.	This is where patients return to reverse paternalism and let their health care practitioners choose what alternative to choose and implement.
Review decisions and consequences	In the last step you experience the results of your decision and evaluate whether or not it has "solved" the need you identified in Step 1. If it has, you may stay with this decision for some period of time. If the decision has not resolved the identified need, you may repeat certain steps of the process in order to make a new decision. You may, for example, gather more detailed or somewhat different information or discover additional alternatives on which to base your decision	This depends on what type of decision was made. If the decision has not resolved the identified need, if a surgery has not been successful, patients often blame their physicians. These physicians however, have been told to decide for them, which is why shared-decision making is of highest importance.

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TABLE II. PATIENT QUESTIONNAIRE

Answer questions as they relate to you.

Check the box(es) that are most applicable to you.

8) About You

a) 1. Your Age

- ☐ Below 15
- ☐ 15-20
- ☐ 20-40
- ☐ 40-60
- ☐ Above 60

b) 2. Your Gender

- ☐ Female
- ☐ Male

c) 3. Your Marital Status

- ☐ Single
- ☐ Married
- ☐ Previously Married

d) 4. Your Employment status

- ☐ Student
- ☐ Employed
- ☐ Unemployed
- ☐ Retired

e) 5. Your Educational level

- ☐ Elementary
- ☐ Intermediary
- ☐ High School
- ☐ College

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9) Doctor-patient Relationship

Please complete the following questionnaire by circling the appropriate answer.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I never ask my doctor for information about a suggested treatment/procedure	1	2	3	4	5
I seek multiple opinions before selecting a surgery/treatment	1	2	3	4	5
I'm confident that my doctor provides me the best treatment	1	2	3	4	5
I don't want my doctor to involve me in decisions about my treatment	1	2	3	4	5
I have a successful shared-decision making relationship with my doctor	1	2	3	4	5
I want my doctor to choose on my behalf	1	2	3	4	5
Doctors know best for patient and they have to decide for them	1	2	3	4	5
It is ethically permissible for patients to allow doctors to act paternalistically	1	2	3	4	5
In critical cases I prefer my doctor to choose on my behalf	1	2	3	4	5
I trust my doctor in everything he says because he is well-known to be the best in his/her field	1	2	3	4	5
I always ask my doctor for information about a suggested treatment/procedure	1	2	3	4	5
It is not necessary to seek multiple opinions before selecting a surgery/treatment	1	2	3	4	5
I don't trust my doctor's ability to provide the best treatment for me	1	2	3	4	5
I want my doctor to involve me in decisions about my treatment	1	2	3	4	5
My doctor-patient relationship lack a successful shared-decision making process	1	2	3	4	5
I refuse to let my doctor choose on my behalf	1	2	3	4	5
Even though doctors know better, they don't have the right to choose for patients	1	2	3	4	5
It is not ethically permissible for patients to allow doctors to act paternalistically	1	2	3	4	5
I prefer to take all my medical decisions by myself	1	2	3	4	5
I don't trust my doctor completely just because he is known to be the best in his/her field	1	2	3	4	5

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Privacy-Preserving Online Monitoring Framework for e-Health Applications

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Abstract— **Many e-health applications track how they are used by patients to enable and validate their effectiveness. While online monitoring can improve the accuracy and quality of e-health applications, there is the potential of serious privacy violations. As e-health applications use online monitoring services, sensitive health data could be exposed to not only the healthcare providers but also the monitoring service providers against wishes of a user. To prevent privacy loss during online monitoring, in this paper, we propose a privacy-preserving online monitoring framework, in short PPoM, that helps providers and users of e-health applications specify their own policies and enforce user privacy policies in systematic manner. To support medical staff and users who do not have enough knowledge and skills on Information Technologies (IT), the PPoM framework provides intuitive and automatic tools that enable non-IT administrators and users to generate privacy policies, enable administrators to automatically insert monitoring code into their e-health applications, and control outgoing messages sent from users' browsers.**

Keywords-e-health application; online monitoring; privacy protection; framework.

I. INTRODUCTION

Online monitoring and analytics are essential techniques to evaluate and enhance the performance of online applications. They help the online service providers improve the usability of their applications by collecting user/usage data and analyzing the performance of applications [1][2]. In general, there are three different approaches to online user monitoring: 1) log file analysis on the server side, 2) proxy-based monitoring, and 3) use of monitoring scripts provided by online monitoring/ analytics services on the client side [3]. In this paper, we focus on the third approach because it is widely used and requires less time and effort to collect, analyze, and visualize user/usage data.

Online monitoring and analytics services, such as Google Analytics [4] and Adobe Analytics [5] have been widely used in a variety of online application areas, such as e-health [6], e-commerce [7], information retrieval [8], and so on. These monitoring/analytics services enable the tracking and recording of user actions and characteristics, such as mouse clicks, frequency of use of an application, time spent in a particular page, media viewed, page navigation sequences, content entered into a textbox, location information, whether a mobile device is being used, and so on.

Among various online application areas, we focus on the healthcare and wellness domains because e-health applications are becoming ingrained into the everyday life of many people. According to Eysenbach [9], e-health is an emerging field at the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. It is an umbrella term that includes a variety of online healthcare applications and systems that use information technologies, such as e-Learning for healthcare, e-Diagnosis, e-Prescribing and online health interventions. By using advanced information technologies, including electronic data management and rich interaction skills, e-health applications are capable of 1) providing personalized services, 2) reducing healthcare cost, 3) ensuring easy access regardless of time and place, 4) ensuring consistent quality of services over time, 5) enabling automated data collection/analysis, and 6) demonstrating the potential for having more honest self-reporting by patients [11]. Many e-health applications have been used for online healthcare education [10], healthcare research [11] and recruitment of its participants [12], collecting healthcare data for research or national healthcare purposes, and conducting healthcare interventions to facilitate disease prevention, disease self-management, and health promotion [13].

Most e-health applications provide several of the following functionalities: 1) self-assessment or self-profiling to recognize individuals' health-related status and in turn provide personalized messages and/or healthcare services, 2) continuous communication with patients/users using interactive tools such as online trackers, and 3) wide dissemination of information related to health and safety, presented in text and/or multimedia format. To accomplish the purposes of e-health applications, on one hand, detailed monitoring is critical to confirm that e-health applications are used correctly and to validate their efficacy. In order to do so, e-health applications must collect detailed, and often identifiable, user data including health information. On the other hand, the protection of user privacy is however critical since e-health applications often deal with very sensitive private data, including health status, medical records, and family health histories. Control over the sharing of this information is of the utmost importance and urgency because indiscriminate monitoring, if inconsiderate of user privacy, may result in private health data being used for unwanted purposes and/or shared with unknown people [1][14][15]. In case of e-health applications, even generic usage data can be damaging if disclosed. For example, disclosure of the login frequency into an online treatment application for substance

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abuse can unintentionally reveal a user's medical status. Consequently, it is urgent and critical for research to examine how we can simultaneously achieve these two important yet opposing goals -- monitoring identifiable user data while protecting user privacy.

To enable e-health applications to conduct trustworthy user monitoring without concern for loss of privacy, in this paper, we propose a new Privacy-Preserving online Monitoring (PPoM) framework. In the PPoM framework, online monitoring services collect user/usage data based on users' policies and users can verify user/usage data being monitored and strictly enforce user policies on the client side. The rest of this paper is organized as follows. In Section II, the requirements for secure online monitoring in e-health applications are identified. In Section III, PPoM framework is proposed and the overall architecture is described. For better understand of practical use, in Section IV, operation flows and example use cases are described in detail. In Section V, evaluation plans are presented. Section VI reports on the related work. The conclusions and future work are presented in Section VII.

II. LIMITATIONS AND REQUIREMENTS

A. Limitations

Existing online monitoring approaches on e-health applications have two major problems, as follows:

1) Lack of systemactic methods to verify and enforce privacy policies mutually agreed by users and providers: To protect user privacy during online monitoring, a user needs to specify his/her preference in data disclosure while the administrators of an e-health application specify their privacy policy describing what kinds of user data might be monitored, what those data are used for, who those data will be shared with, and how user data are maintained. Users and administrators can specify their policies using policy languages such as P3P [19] and WS-XACML [20]. Once a user agrees to an application's policies, the enforcement of agreed policies has been primarily relied on the honor system [16] within the application without any external verification process. To ensure user privacy, the federal Health Insurance Portability and Accountability Act (HIPAA) [17] stipulates that a healthcare component must not disclose protected health information to another component (HIPAA 164.105.(a)(ii)) with only a few exceptions (HIPAA 164.512). However, it is difficult to expose violations of HIPAA regulations within e-health applications in existing approach. If a provider embeds monitoring code and/or third-party data-collecting ads in its webpages, private data can easily be released regardless of users' wishes. Although this is an obvious violation of HIPAA rules, there are no solutions to systematically detect the application's fraud and prevent user data from undesirable use and disclosure.

To protect user privacy from undesirable use, some online applications anonymize/de-identify user data by deleting identifiers in original data but such anonymized data can often be re-identified/de-anonymized [18]. It is hence not enough to hide user identifiers and we need a new method not to share critical information based on user preferences. In addition, anonymization might not be applicable to some e-health applications that require identifiable user data for personalized services. Without a strong enforcement method, many users are unlikely to consent to online monitoring.

2) Need for professional IT knowledge and skills: At present, professional IT knowledge is needed for developing e-health applications with appropriate privacy-preserving monitoring. For example, to specify privacy policies of an e-health application, an application administrator must understand privacy policy languages, such as P3P [19] or WS-XACML [20] and be able to precisely specify the application's policy in that language. In addition, to use an online monitoring service, the administrator must understand the client-side monitoring code (e.g., in JavaScript), and be able to manually insert privacy-preserving code into the original source code (possibly using different languages) for each web object or webpage being monitored. Hence, administrators of e-health applications need to understand at least one language to integrate privacy-preserving monitoring into applications. This is however an impractical expectation for many non-IT administrators, such as doctors, nurses, health educators and communicators. Not only for non-IT clinical staff who manage e-health applications but also for average users who use e-health applications, it is difficult to exactly specify privacy policies and enable their applications/browsers to protect user privacy. The lack of IT knowledge of administrators and users of e-health applications significantly increases the need for easy-to-use tools for a privacy-preserving framework.

B. Requirements

Towards trustworthy and highly usable online monitoring in e-health applications, the following requirements should be satisfied:

1) For strict enforcement of user privacy policies

- Online monitoring services that are aware of user privacy policies rather than application policies.
- Verification methods to ensure that an application complies with policies mutually agreed by providers and users on user side.
- Enforcement methods to protect user privacy on user side in case of privacy violation during online monitoring.

2) For practical use by non-IT users and staff

- User-friendly interfaces to intuitively specify privacy policies and monitoring objects.
- Automatic generation of privacy policies for e-health applications.
- Automatic conversion of existing e-health applications to privacy-preserving applications in which privacy-aware monitoring code is embedded.

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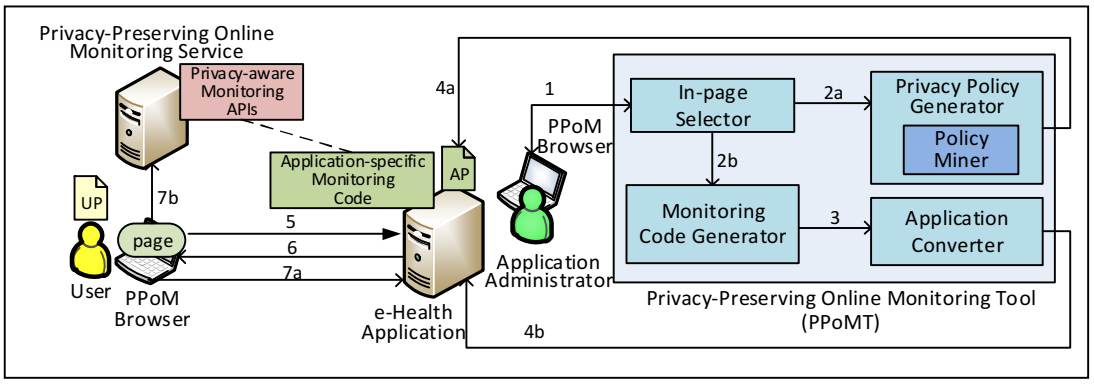

Figure 1. Overall architecture of PPoM framework.

III. OVERALL ARCHITECTURE

To fulfill the requirements described above, in this paper, we propose a new PPoM framework that rigorously protects user privacy by referring user policies and enforcing them on user side. For convenient and easy adoption by e-health application providers, PPoM includes easy-to-use tools for users and providers. The overall architecture of PPoM framework is shown in Figure 1. The detailed descriptions for each component are following:

A. PPoM Service

The problems of existing online monitoring services are twofold. First, users are forced to choose between two options: opt-in or opt-out, and not allowed to choose data to be monitored in fine-grained level. Second, user data are collected based on the decision of providers. Once a user gives consent to monitoring (opt-in), all user activities on the web objects in which monitoring code is embedded are captured regardless of users' privacy preferences. None of existing services considers users' privacy preferences during monitoring.

To address the issue of ignorance of user preferences during monitoring, we propose a PPoM service that gathers only authorized user/usage data that users allow to monitor. By specifying privacy policies, users determine which data can be monitored. User policies will be then enforced by a trustworthy third-party monitoring service, the PPoM service. Using the PPoM service, e-health applications can guarantee effective protection of user privacy by providing a way to enforce user policies in a systematic manner rather than simply providing a written agreement. The concrete enforcement framework assists both monitoring services and e-health applications in building better reputations and accelerates active participation in e-health applications without concerns about privacy leakage. In addition, it can be used to compel and enable e-health applications to obey HIPAA regulations.

B. Privacy-Preserving User Browser

If an e-health application is trustworthy and both users and administrators can correctly specify their own policies, then existing approach may be able to guarantee secure online monitoring. However, this protection presumes the application's honesty and the user's ability to specify privacy policies precisely. Let us assume that an e-health application publishes untrusted policies that differ from its actual monitoring behavior. Once user's policies and the application's policies are matched, a user will start interaction with the dishonest application and his browser will send unconsented data to the application.

However, user privacy must be protected even if a user is exposed to untrustworthy parties, such as indiscriminate monitoring/analytics services that conduct online monitoring in violation of user privacy, naïve applications that do not have their own privacy policies or dishonest applications that write and/or enforce their policies dishonestly. To address the above security requirement, we propose a PPoM-enabled web browser (in short, PPoM browser) as a user-side protection. For easy adoption, we plan to implement a browser extension that enables existing browsers (e.g., Explorer and Chrome) to perform following tasks:

1) It presents all user data being monitored by online monitoring service(s) in web pages: A PPoM browser displays all monitoring data and recipients of data on the screen by analysing source code of web pages.

2) It allows a user to decide which usage and his/her data can be disclosed: A PPoM browser inspects data types, data values, and destinations of all outgoing message according to user policies. If it detects malicious monitoring that violates user policies, it alerts a user to unauthorized monitoring. For example, if the user decides to disclose his/her medical history to a first-party (e.g., an e-health application website), then a PPoM browser only allows outgoing messages to the e-health application and blocks other messages to other entities (such as ad companies or social networking sites) even if the application does not have its own privacy policy or inserts monitoring code to collect his/her medical history data.

3) It refines the user's privacy policies based on updated user preferences: If a user' privacy policies are naïve or incorrect, the proposed approach based on user policies cannot protect user privacy successfully. However, It is very difficult for average users to specify precise privacy policies because it is hard to understand the correlation between description of user data in privacy

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policies and web objects in web pages. To enhance the proposed PPoM framework, a PPoM browser allows users to refine their preferred policies by intuitively selecting what user/usage data can be monitored in web pages.

C. *Privacy-Preserving Online Monitoring Tool*

As pointed out in Section II. A, it is difficult for non-IT administrators to have professional IT knowledge and skills that necessary for trustworthy online monitoring. In this paper, we propose the PPoM Tools (PPoMT) to help health professionals. PPoMT enables non-IT clinical staff to specify privacy policies for their healthcare applications, and/or to easily convert their applications into privacy-preserving applications that analyze user/usage data without violating user privacy. While motivated by the needs of non-IT administrators, this tool could also improve the efficiency of developers who are required to insert monitoring code into their applications. The PPoMT consists of four individual tools: the In-page Selector, the Monitoring Code Generator, the Privacy Policy Generator, and the Application Converter. The detailed explanations for each tool are following:

1) In-page Selector: It is a server-side software module that is capable of generating modified webpages that have user-friendly interfaces for selection of web objects to be monitored and corresponding policies and delivering user selections to the Privacy Policy Generator and the Monitoring Code Generator. It sends modified webpages to the PPoM browser of an administrator. By clicking on web objects that are displayed in the PPoM browser (e.g., a button, link, text, image, or video), the administrator can select which objects to monitor without any IT knowledge and skills. Additionally, he can declare corresponding privacy policies.

2) Monitoring Code Generator: It generates privacy-aware monitoring code by receiving an administrator's selection on monitoring objects and associated privacy policies from the In-page Selector. The generated code will be varied depending on monitoring services.

3) Privacy Policy Generator: It helps non-IT administrators who may be unfamiliar with online privacy policy languages publish privacy policies for their own applications. Using the Policy Miner, it derives the privacy policies for a given application by analyzing all monitoring objects and corresponding privacy policies that are selected by the administrator.

4) Application Converter: It helps non-IT administrators to update source code of an existing application by assisting them in inserting the privacy-aware monitoring code generated by the Monitoring Code Generator. Once the code modifications are made, an administrator needs to deploy the modified source code in their server.

IV. PRIVACY-PRESERVING MONITORING USING PPOM

In this section, we explain how PPoM protects user privacy during online monitoring and supports non-IT administrators and users by describing operation flows and example use cases from the point of view of administrators and users.

A. *For online healthcare providers*

Let us assume that Alice, a medical doctor, administrates an e-health application that assesses the impact to people following exposure to traumatic events. To trace patients' activities and collect health-related data, Alice wants to conduct online monitoring on her applications, but it is impossible for her to use existing online monitoring services due to lack of IT-related knowledge.

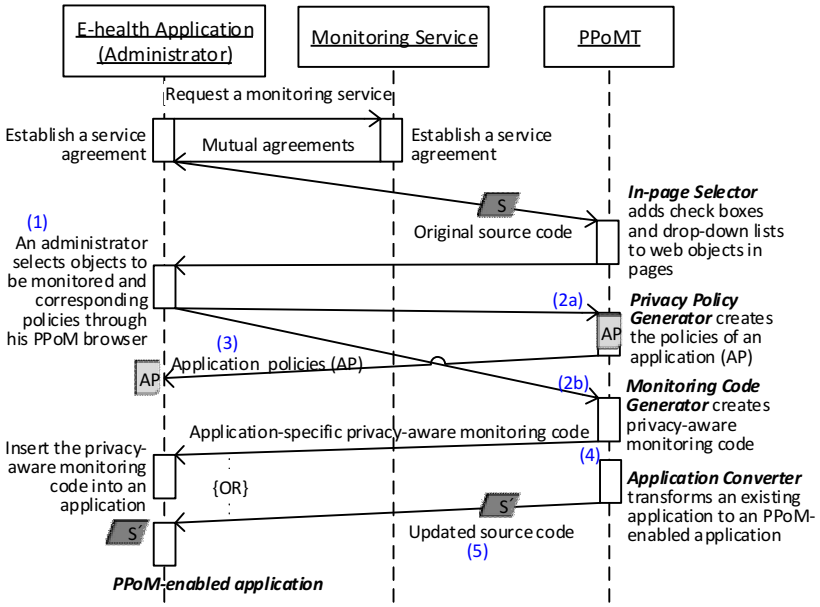

Figure 2. Operation flow of administrators of e-health applications in PPoM.

If she uses the PPoMT, she can easily transform her application into a monitoring-enabled application without any IT knowledge. For better understanding, let us look at its operational flow in detail. First, she needs to upload the source code of her application or enter the URL(s) of the application's webpage(s). Second, she selects objects to be monitored through the user-friendly interfaces generated by the In-page Selector, and specifies corresponding privacy policies (Figure 1.(1) and Figure 2.(2)). Third, her selections are delivered to the Policy Generator (Figure 1.(2a) and 2.(2a)) and the Monitoring Code Generator (Figure 1.(2b) and Figure 2.(2b)). Forth, the Privacy Policy Generator then creates the applications' policies by analyzing selected monitoring data and policies, while the Application Converter (which enables the application to perform privacy-preserving monitoring by inserting monitoring code generated by the Monitoring Code Generator into the original source code (Figure 1.(3) and Figure 2.(4)) produces the updated source code. Fifth, Alice deploys the created application policies (Figure 1.(4a) and Figure 2.(3)) and the updated source code in the application server (Figure 1.(4b) and Figure 2.(5)).

B. *For Users*

Let us assume that Bob is one of Alice's patients. Alice recommends Bob to use her e-health application every week to assess his mental and physical health but he hesitates to use the application due to privacy concern. If Bob uses the PPoM browser, he may want to use an e-health application without privacy loss. Towards this, Bob is first required to specify his own privacy policies and store his policies in his browser before using an e-health application (Figure 3.(1)). His PPoM browser then compares his privacy policies and application policies when he enters a url of Alice's application (Figure 3.(2)). If they match, the application server sends PPoM-enabled pages which privacy-aware monitoring code is embed in (Figure 1.(5)(6) and Figure 3.(3)). As he interacts with the application, the PPoM browser displays all user/usage data being monitored to enable users to verify privacy protection during online monitoring (Figure 3.(4)). If there is no privacy violation, the privacy-aware monitoring code collects only authorized user data according to policies of him specified by him for the sake of himself (Figure 1.(7a)(7b) and Figure 3.(5)). To ensure enforcement of user policies, his PPoM browser blocks outgoing messages that violate his privacy policies on the user side (Figure 3.(6)).

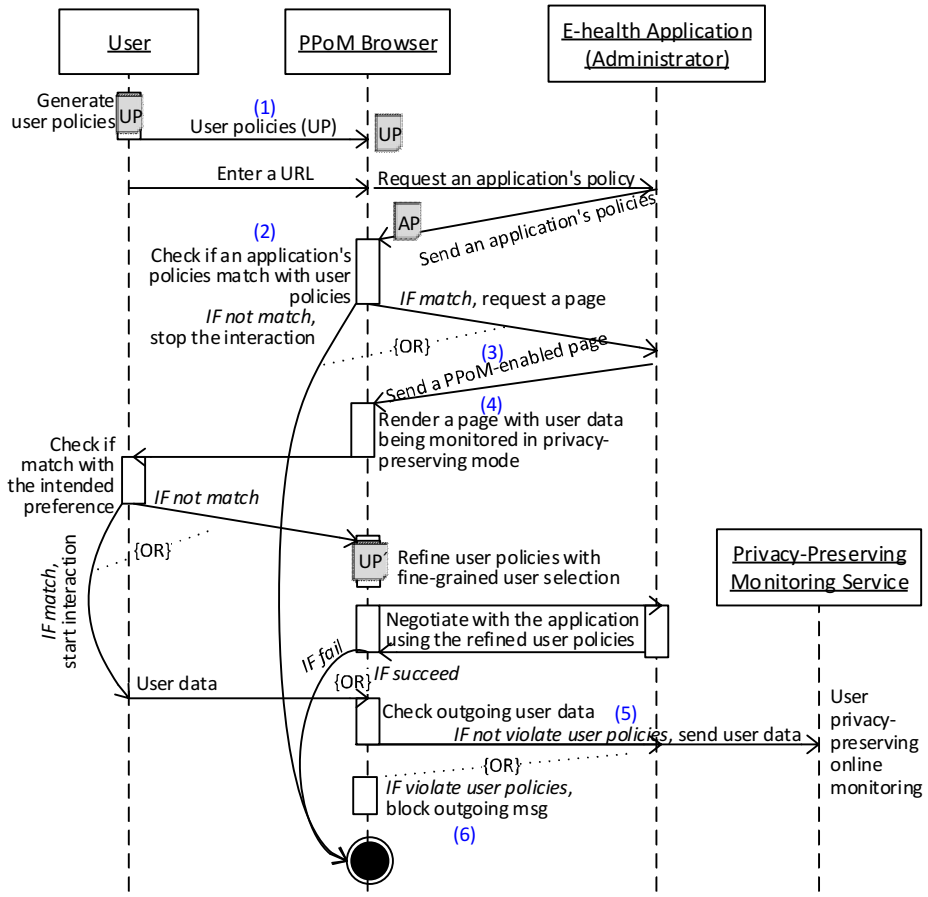

Figure 3. Operation flow of users in PPoM.

V. EVALUATION PLAN

To evaluate the performance of the proposed privacy-preserving monitoring service, we will calculate the ratio of the number of all monitoring data ($a+c$ in Table I) to the number of unauthorized but collected data (c in Table I). In addition, we will also test the successful blockade ratio of the number of messages containing unauthorized data ($g+h$ in Table II) to the number of blocked messages among them (g in Table II). We will plan to test the developed tool, PPoMT, by comparing a user's selections of monitorable data and corresponding privacy preferences with monitoring scripts or source code that generated by PPoMT. To evaluate the correctness of the generated privacy policies, we will create a variety of anticipated privacy policies, use PPoMT to generate privacy policies, and compare the resulting policies with the anticipated policies.

TABLE I. USER DATA MONITORED BY THE PROPOSED PRIVACY-PRESERVING MONITORING SERVICE

	Monitored	**Not monitored**
Allowed	*a*	*b*
Not allowed	*c*	*d*

TABLE II. OUTGOING MESSAGES FROM A PROPOSED USER AGENT

	Sent	**Blocked**
Allowed	*e*	*f*
Not allowed	*g*	*h*

VI. RELATED WORK

A. Provider-side privacy protection for online monitoring

To guarantee secure user monitoring, a few methods have been proposed by providers of online applications and monitoring services. Some third-party advertising companies have voluntarily begun to insert an 'Adchoices' icon into their ads to increase user awareness of online tracking. However, it has been found that the icon was not very effective at making users aware of tracking occurrences [21]. As a middleware approach, Privad [22][23] is proposed to conceal a user's activities from an advertising network by interposing an anonymizing proxy between the browser and the ad network. However, the adoption of a proxy-based middleware may not be a feasible solution to small-size e-health applications because of its huge overhead requirements. In addition, it is useless if an e-health application requires identifiable user data to analyze performance of applications at the individual level.

B. User-side privacy protection for online monitoring

1) Browser-based approaches: To protect user privacy in user side, browser-based approaches have been proposed. Adnostic [24], a browser extension, is capable of behavioral profiling and targeting in users' browsers to select effective ads while not sending user data to third-party ad companies. RePriv [25] enables browsers to conduct user interest mining and only share the resulting encapsulated interests with third-parties. Both Adnostic and RePriv have only focused on targeted advertising and/or personalization but have not considered online monitoring services. As a simple solution to indiscriminate online monitoring, using opt-out cookies and/or a blocked-application list have been recommended. Opt-out cookies are, however, fragile because they can be easily disabled or deleted by a third party [26][27]. Setting a block list in a browser can effectively block malicious applications but currently this approach blocks any listed application in its entirety and does not support fine-grained blocking at the data level.

2) Policy-based approaches: As a policy-based protection approach, Privacy Bird [28] has been proposed. It is a P3P user agent that reads P3P policies of online applications and lets users know whether the application policies and user preferences are matched. If policies are not matched, a bird icon turns red. A user can get information by clicking on a red bird icon. However, Privacy Bird is only able to check the acceptability of application's P3P policies, so users cannot check all user data monitored at the application's data level.

VII. CONCLUSION AND FUTURE WORK

The lack of reliable and effective methods of privacy protection has been the biggest obstacle to the growth of e-Health applications. Without a suitable solution, people keep hesitating to use e-Health applications, even though those applications help users access healthcare services in easy and convenient way at the reduced cost. To address the privacy protection issue above, in this paper, we proposed the PPoM framework that protects user privacy in both the application side and the user side so that secure online monitoring can be guaranteed in the entire process of online monitoring. We believe that PPoM accelerates practical use of e-health applications. Towards this goal, a few challenges need to be pursued in the future:

- Development of the privacy policies to specify preferences on healthcare data in fine-grained level.
- Development of a privacy-preserving monitoring service that protects user privacy based on user policies.
- Development of the PPoM browser and tools.
- Performance tests on the other individual components and an integrated component and a field test associated with actual clinical trials.
- Development of a threat model for PPoM and security test using a threat model.

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Systematic Review of Obesogenic Environmental Determinants of Diet and the Implications of Obesity Prevention and Intervention Efforts

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***Abstract*— The environment plays a crucial role in the development of obesity. Obesity rates continue to escalate, bringing into question the efficacy of prevention, intervention, and treatment efforts. This paper identifies the previous research examining obesogenic environmental factors and sets out to determine whether physical, social, cultural, and economic environmental factors are associated with obesogenic dietary behaviors. The study searched five databases for full-text English articles, of which 103 were included in the literature review. The selection was based on keywords searching, peer-reviewed publications, stated research methodology, strategic analysis, and substantial increments in knowledge. One of the results showed an increasing pace of urbanization, media influence, and advertising emphasis on unhealthy food are associated with obesogenic dietary behavior. The discussion focuses on the most susceptible factors for obesity and the implications for future research in communities with a dense population. The objective of addressing the obesity epidemic is to employ strategies to curtail sugar use, restrict marketing efforts of unhealthy food, and increase the availability of healthy food.**

Keywords-obesogenic; food environment; advertising; diet study; prevention

I. INTRODUCTION

Research has shown increasing attention on how the environment affects population health [1] [2]. Considerable studies have evidenced that population obesity was a product of the environment 30 years ago, and environmental changes are associated with epidemic obesity rates in all age groups [3] [4]. The influence of environmental stimuli on obesity prevalence must be affected to some extent by people's dietary and physical activity behavior, which ultimately leads to an imbalance in energy intake and thus to obesity [5] [6].

The obesogenic environment is defined as an environment that influences or promotes obesity in individuals or populations, which constitutes all surroundings, opportunities, or life conditions that lead to obesity [7]. The problem of the dramatic increase in obesity is complex, and may involve factors related to socioeconomic status, personal preferences, family habits, physical factors, and perhaps genetics. The theoretical framework from the consumer socialization perspective suggests that factors influencing food choice operate at four distinct levels: individual (psychological, biological, and behavioral factors), interpersonal (family, friends, and peer networks), community (accessibility, school policy, and local facilities), and societal (mass media, advertising, social and cultural norms, production and distribution systems, and pricing policies) [9] [30] [39].

Prior reviews of the obesogenic environment literature indicated that modern sedentary activities promote the overconsumption of food, thus causing weight gain [11] [22]. However, empirical study remains lacking in terms of an appropriately designed research investigating associations of environmental factors with individuals' attitudes, genetics, and societal development. Insight probably can be gained by improving theory and methods of research [8] [29]. This study focuses on the measurement and evaluation of the obesogenic environment. Obesogenic food environments are considered to facilitate high energy intake by increasing access to stores that promote unhealthy food choices. In Section 2, three research questions are discussed and systematic review method is adopted to identify the previous research in the literature in relation to obesity and the food environment.

II. QUESTIONS AND METHODS

RQ.1 What is the previous research focus on the measurement and evaluation of the obesogenic environment?

RQ2. What risk factors, such as the physical, social, cultural, and economic environment, are associated with obesogenic dietary behaviors?

RQ3. How to use obesity prevention and intervention to decrease obesity?

Systematic review is a method often used to investigate a broad set of literature related to environments linked to obesity study [20] [21] [24]. The coding category was adopted from previous studies and included the publication year, author(s), affiliated organization, country, study design, main environmental determinants, scale of the geographical study, postulated relationship of specific risk factors (i.e., physical, social, cultural, and economic environment; individual, interpersonal, population, and global level), and analysis between the environment and weight status [22] [32]. The inclusion criteria and procedure are discussed in the followings section.

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Inclusion criteria

A comprehensive scholarly and multi-disciplinary full text databases including Academic Search Complete [51], Health Reference Center [52], Medline [6] [24], Springer Link[53], and Proquest Medical Library [22] [32] were searched for studies published from 2004 onward in full-text English articles. This study included only peer-reviewed articles that present advances in assessment methods, analytical result, up-to-date research studies or substantial increments in knowledge examining obesogenic environmental factors and evidence. A systematic study was recommended to assess at least one environmental factor. The search terms such as "diet study" and either "obesogenic," "intervention," "prevention," "obesity," "food marketing," "food advertising," or "mass communication campaign" were included. The researchers screened 3,139 de-duplicated records, of which 103 met the inclusion and exclusion criteria. Inter-rater percentage agreement between reviewers and Cohen's kappa coefficients were calculated: Academic Search Complete, 90% and 0.213; Health Reference Center, 92% and 0.392; Medline, 95% and 0.421; Springer Link, 89% and 0.316; and Proquest Medical Library, 91% and 0.396, respectively. All disagreement in coding was discussed and consensus was reached by the coders and authors. In Section 3, the research findings are reported by answering the three research questions.

III. RESEARCH FINDINGS

A total of 99 journal articles and 4 book chapters were included in this study. The distribution of the publication year for the obesogenic environmental studies has been increased steady. Two articles were -published in the year of 2004 and 20 publications were found in 2014. The publication of obesogenic environmental studies has increased and the prolific years were 2014 (n = 20, 19%), followed by the years of 2010 (n = 14, 14%), 2013 (n = 12, 12%), and 2006 (n = 12, 12%).

Examining the authors' nationality of affiliated organization indicates the diversity of journal contributors. Authors' affiliated organization from European countries were the main source of evidence (n = 58, 52%), followed by America (n = 33, 29%), Oceania (n = 10, 9%), and Asia (n = 8, 7%). Specifically, the nationalities of the authors' affiliated organization were mostly American (n = 29, 26%), followed by British (n = 20, 18%) and Finnish, Norwegian, Swedish, and Australian with the same number of papers published (n = 8, 6%).

Table 1 illustrates the research methods used for the previous research published related to obesogenic environment determinants of diet. The most frequently used survey method was experiment (n = 36, 35%), followed by questionnaire (n = 19, 18%), review (systematic and scoping, n = 19, 19%), and mixed qualitative and quantitative method (n = 12, 12%). The previous 19 review studies only recruited publications with human as the subject of research. However, in this study, the result found 15 studies adopted mice or white swine for experiment to examine and improve the potential interactive effects of diet, exercise, and genetic background. These studies suggest that physiological reactions may not merely increase in response to obesity but may also have a direct causal role in obesity and biological resistance. Another four research methods such as content analysis, interview, observation, and focus group were used with a relatively low percentage in obesogenic environment study. We also discovered that a large proportion of articles omitted crucial information on their methodology (n = 13, 13%), population description (n = 14, 14%), and sample size (n = 31, 30%).

TABLE 1 RESEARCH METHOD USED FOR THE 103 STUDIES RELATED TO OBESOGENIC ENVIRONMENT DETERMINANTS OF DIET

Method	Frequency	Percentage
experiment	36	35%
Questionnaire	19	18%
systematic review	10	10%
scoping review	9	9%
mixed method	12	12%
content analysis	2	2%
Observation	1	1%
Interview	1	1%
focus group	0	0%
Unclear	13	13%
Subtotal	103	100%

Table 2 presents a summary of 14 selected studies with advances in assessment methods that specifies risk factors, such as physical, social, cultural, and economic environment, associated with obesogenic dietary behaviors. The most susceptible factors for obesity according to obesogenic studies confirm the importance of the societal development of urbanization, media influence, and marketing activities (n = 11, 38%), followed by specific cultural food diet (n = 9, 31%), physical activity and habit (n = 7, 24%), and product-related factors (n = 2, 7%). The effects of eating habits and preferences have been investigated at several levels with substantial increments in knowledge by five studies listed in Table 2 [13] [15] [17] [18] [44].

Table 3 summarizes the solutions to increasing obesity proposed by eight studies. The method of diet intervention and policy restriction for television advertising is shown. Intervention (n = 6, 75%) and prevention (n = 2, 25%) efforts such as diet and physical activity are indicated while regulation of food industry and treatment of obese population lacks equal research attention. In Section 4, the discussion was extracted from the included studies emphasizing the food environment, marketing efforts, and prevention and intervention efforts from communication and marketing perspectives regarding an unhealthy food environment.

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TABLE 2 SUMMARY OF EXISTING STUDIES SPECIFYING RISK FACTOS OF PHYSICAL, SOCIAL, CULTURAL, AND ECONOMIC ENVIRONMENT

	Author (Year)	Objective/Aim	Population description	Sample description	Conclusion related to risk factors
1	Murphy, M. & Mercer, J. G. (2013) [44]	The aim of this review is to bring together existing knowledge of how food components affect anxiety at various stages of development, while highlighting some major gaps in our current understanding.	n/a	n/a	Assembled from study of preclinical models of diet challenge from gestation to adult life, supports the role of dieting as an important connection between psychology, physiology, and behaviour. Analogous processes in the human population in our current obesogenic environment are likely to contribute to individual and societal challenges in this area.
2	Hoek, J. & Gendall, P. (2006) [25]	To examine an alternative means of framing the debate and explore the role advertising plays in reinforcing behavior patterns.	n/a	n/a	In addressing obesity, policymakers have directed their efforts primarily at creating more informed individuals, without first having created a regulatory environment that will support social marketing and education programs.
3	Jääskeläinen A. et al. (2014) [5]	To study prevalence of stress-related eating and its association with overweight, obesity, abdominal obesity, dietary and other health behaviors at the age of 16.	n/a	3,598 girls and 3,347 boys	Stress-related eating is highly prevalent among 16-year-old girls and is associated with obesity as well as adverse dietary and other health behaviors among both genders, but intrauterine conditions are seemingly uninvolved.
4	Feng, J., et al. (2010) [20]	The aim is to give an overview of the wider environmental determinants of diet such as the national food supply, food availability and accessibility in different settings and economic food environment in relation to socio-economic status.	n/a	87 papers	There was very little similarity in methods and approaches which prevented estimation of pooled effects. The great heterogeneity across studies limits what can be learned from this body of evidence.
5	Firk, S. F. L., Penney, T. L., & McHugh, T. L. F. (2009) [21]	This presents a major challenge towards our understanding of environmental research for obesity, and the development of a desperately needed contextualized evidence base to support action and policies for curbing this epidemic.	n/a	146 primary studies	Gaps in the literature were clearly identified at the level of the macro-environment, and the political and economic micro-environments, highlighting key areas where further research is warranted if we are to more fully understand the role of the obesogenic environment.
6	Giskes, K., et al. (2011) [22]	This study examined whether physical, social, cultural and economic environmental factors are associated with obesogenic dietary behaviors and overweight/obesity among adults.	n/a	28 papers	Associations between the environment and weight status are more consistent than that seen between the environment and dietary behaviour. The environment may play an important role in the development of overweight/obesity, however the dietary mechanisms that contribute to this remain unclear and the physical activity environment may also play an important role in weight gain and obesity.
7	Adair, L. S. & Popkin, B. M. (2005) [18]	To examine the extent to which child dietary patterns and trends are changing globally.	Nationally or regionally representative data from 4 countries	25,247 Participants from USA, 4,253 from Philippines, 4,758 from Russia, and 7,417 from China	This research suggests that globalization of the fast food and nutrition transition. However, the contribution of fast food and soft drinks to the diet of children remains relatively small in China, Russia, and Philippines. Other modern food sectors are beginning to affect child eating patterns in several countries undergoing.
8	Ambler, T. (2006) [37]	This paper reviews previous research on the extent and nature of food promotion to children and the effect and promotion has on children's food knowledge, preferences and behaviour. It intends to ascertain reliability that appear to have been drawn by the UK Food Standards Agency for national policy making.	n/a	Hasting's study	The paper's first conclusion is that considering the effect of branded food and drink promotions outside their socio-economic and cultural context is unreliable. Second, while there are promotional effects at the brand level, these do not extend to product category level, still less overall diet, where the evidence is thin at best.

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9	Chang, A. (2013) [15]	This study conducted a comparative analysis of the media and food environment in China to determine a method to combat childhood obesity.	n/a	46 brands with 489 television commercials	Preschool children can demonstrate an understanding of cultural dietary rules. Young children, even at three years of age, can recognize and implement cultural rules regarding appropriate food choices for meals. Although children of all ages are affected by advertising, those between seven and eleven years of age are most likely to be targeted and persuaded by advertising.
10	Chandon, P. & Wansink, B. (2012) [13]	The review begins with an examination of the multiple ways in which 1) food pricing strategies and 2) marketing communication (including branding and food claims) bias food consumption. It then describes the effects of newer and less conspicuous marketing actions, focusing on 3) packaging (including the effects of package design and package-based claims) and 4) the eating environment (including the availability, salience, and convenience of food).	n/a	Updating two existing reviews	To summarize how food marketing has made us fat, it is most likely through increased access to continuously cheaper, bigger, and tastier calorie-dense food. Throughout, this review underscores the promising opportunities that food manufacturers and retailers have to make profitable “win-win” adjustments to help consumers eat better.
11	Drewnowski, A., et al. (2014) [15]	To compare the associations between food environment at the individual level, socioeconomic status (SES) and obesity rates in two cities: Seattle and Paris.	n/a	7,290 participants	Lower SES was linked to higher obesity risk in both Paris and Seattle, despite differences in urban form, the food environments and in the respective systems of health care. Cross-country comparisons can provide new insights into the social determinants of weight and health.
12	Edwards, J., Engstrom, K. & Hartwell, J. H. (2005) [17]	The purpose of this paper is to consider the facts from a food service perspective, the role and relevance of portion size, product bundling and all you can eat buffets in the current debate on overweight and obesity.	n/a	n/a	The causes of overweight and obesity are multifactorial, complex and in many areas not particularly well researched. In many instances it seems almost as if the consumer and food service operator, through the media and government, are blaming each other for the current situation, and then expecting the other to somehow find a solution.
13	McMullan, J. & Keeney, S. (2014)	This article reviews the previously published literature on the social and environmental factors which influence children (aged 3–5 years) to be obese/overweight and the accuracy of parental perceptions.	Studies published between 1995-2013 on childhood obesity and environment, and socioeconomic status.	n/a	Obesity levels are on the increase in today’s society and habits are being passed from parents to children, with family lifestyle choices often influencing this health condition. The results confirm the available research does not allow robust identification of ways in which that physical environment influences adult weight status.
14	Goris, J. M. et al., (2009) [23]	To estimate the contribution of television (TV) food advertising to the prevalence of obesity among 6–11-year-old children in Australia, Great Britain (England and Scotland only), Italy, The Netherlands, Sweden and the United States.	Data of 6-11-year-old children in six Western countries.	n/a	The contribution of TV advertising of foods and drinks to the prevalence of childhood obesity differs distinctly by country.

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TABLE 3 SUMMARY OF STUDIES IN PROVIDING SOLUTIONS TO INCREASING OBESITY THROUGH PREVENTION AND INTERVENTION

	Author (Year)	Objective/Aim	Population description	Sample Size (n=)	Conclusion of prevention and/or treatment
1	Maynard, M., et al. (2009)	This exploratory study assesses the feasibility, efficacy and cultural acceptability of child- and family-based interventions to reduce risk factors for childhood and adolescent obesity among ethnic minorities.	n/a	44 children	The emergent findings suggest that while the school setting may be better for the main implementation of healthy lifestyle interventions, places of worship provide valuable opportunities for family and culturally specific support for implementation.
2	Brown, T. & Summerbell, C. (2009)	To determine the effectiveness of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity.	n/a	38 studies	The finding suggests to combine diet and physical activity school-based interventions to help prevent children becoming overweight in the long term.
3	Hammarstrm, A. et al. (2014)	The aim of this study is to explore barriers and facilitators to weight-loss experienced by participants in a diet intervention for middle-aged to older women in the general population in Northern Sweden.	Middle-aged to older women to a weight-lose program	24 women	It is important to include drop-outs from diet interventions in order to fully understand barriers to weight-loss. A gender-relational approach can bring new insights into understanding experiences of barriers to weight-loss.
4	Garcia-Calzon, S. A. et al. (2014) [48]	The aim of this study is to assess the relationship between telomere length (TL) and changes in adiposity indices after a 5-year nutritional intervention.	Women (60–80 years) & men (55–80 years) with no previously history of cardiovascular disease, but at high cardiovascular risk	521 participants	The research suggests that TL is inversely associated with changes in obesity parameters. The assessment of TL can provide further insights for biological pathways leading to adiposity.
5	Doyle-Baker, P. K. et al. (2011)	The biochemical evaluation of a health intervention program investigates the impact of progressive exercise intensity in overweight and obese children.	Overweight and obese male (M) and female (F) children (aged 5-10) in Canada	25 children	The high-intensity exercise within a comprehensive health program includes nutrition education improves the lipid and physiological health profiles of obese children.
6	Zambrano E., Mart´ınez-Samayoa1, P. M., Rodr´ıguez-Gonz´alez1, G. L., & Nathanielsz, P.W. (2010)	This paper discusses whether maternal obesity-induced programming outcomes are reversible by altered dietary intake commencing before conception.	female rats	n/a	Obesity involving women of reproductive years is increasing dramatically in both developing and developed nations. This study shows reversibility of adverse metabolic effects of maternal obesity on offspring metabolic phenotype.
7	Birch L. L. & Anzman, B. L. (2010) [3]	The article provides examples of learning paradigms— familiarization and associative and observational learning—that present opportunities for parents and caregivers to restructure children's environments in early life, increasing the likelihood of healthy weight-status outcomes in the context of the current obesogenic environment.	n/a	n/a	This study uses a developmental perspective and argues that this probabilistic outcome is not predetermined. Effective early preventive interventions are urgently needed to address the obesity epidemic among all segments of the population, but especially among groups at highest risk of childhood obesity.
8	Edmond, S.(2006) [164]	To ensure that the public policy objectives are met without unnecessarily and unjustifiably damaging the broadcast and advertising industries.	n/a	n/a	Government's report on obesity is important in leading healthier and more active lifestyles. The advertising industry wants to work in partnership with the government, and other stakeholders, to ensure that it gets the balance right between consumer concerns and business needs.

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IV. DISCUSSION

With an estimated 2.1 billion people overweight globally, tackling obesity is one of the most serious challenges, requiring a societal and systems change in our approach to food, lifestyle, and the environments [41].

A. Food Environments

British researchers concluded that food retail access in urban areas does not have a profound or prolonged effect on dietary patterns [19]. However, for the Chinese community, vending machines, mini grocery shops, convenience stores, and supermarkets were all found to sell large quantities of sweetened beverages, snacks, or high-calorie, high-fat, and low-nutrient food [28] [38]. This food supply led to the association of unhealthy food products and obesity. The patterns of food product types lacked the elements of delivering essential food groups and correct dietary information [34]. The literature tends to indicate that consumers in all age groups are likely offered and encouraged to choose a diet with super-saturated fat and excessive salt. In addition, the research showed the importance of urban–rural differences and the contribution of fast food and soft drinks in children's diets [12] [18]. Although snacks and drinks remained relatively insignificant in the total diet of most people, the researchers emphasized that the globalization of the fast food and other local or modern food sectors is affecting our eating patterns and exposes us to the threat of nutrition transition towards higher-fat diets in all regions of the world [34] [38].

B. Marketing Efforts toward Obesity

Several studies examined the array of food products available on television and concluded that fast food restaurants, sweetened soft drinks, and sweetened cereals consistently dominate television food advertising. The identified patterns of food product types are commonly associated with unhealthy diets [42] [43]. For example, the exposure of sampled youth to 100 TV ads for sugar-sweetened soft drinks was associated with a 9.4% increase in their consumption of soft drinks [10]. Thus, advertising has been accused to be a catalyst in problems of obesity for some age groups and in some countries [15] [23] [37]. For marketing efforts related to obesity research, sufficient studies have shown an association between promotional activity and children's food knowledge, preferences, and their choices of daily snacks at playtime [13] [16] [25] [26] [33] [36] [40]. These studies have supported the notion that children's age is a critical factor in the influence of advertising, especially in regard to nutrient imbalance diets.

C. Preventions and Interventions in Increasing Obesity

The intake of fruit, 100% juice, and vegetable and regular physical activity are advised to be healthy behaviors related to obesity prevention at the individual level [31]. The emphasis of parental control may be another possible solution. The portrayal of family togetherness and parents' role is effective for promoting a healthy eating environment, and also helps in regulating children from over-engaging in sedentary activities. For example, a survey [28] indicated that Chinese parental influence, especially the father's role modelling, is significantly related to attraction toward physical activity in overweight children. For boys, both the father's and mother's influence is strong. Parenting style such as role modelling and encouragement can positively influence an overweight child's physical activity involvement.

Furthermore, modifying the larger context and the microenvironment associated with health education for knowledge of nutrient dense diets is crucial. It is argued that school environments should provide access to healthy food and help reduce exposure to cues that encourage overeating or underactivity [15] [33]. At the community level, the solution to increasing obesity by employing interactive and mass media campaigns to change health behavior for health promotion is proven to be effective [24]. The goals of public awareness campaigns are to increase the awareness of the obesogenic environment, improve access to a healthy diet, and tackle obesity problems. In Section 5, the limitation and suggestions for future research are included in the conclusion.

V. CONCLUSION

This review provides a systematic and objective process for collecting knowledge applied to diet-related behavior in an obesogenic environment. The reviews of 203 previous studies showed that few investigations of environmental associations have been replicated, and that most studies used weak research designs and non-validated self-report measures.

Medical studies have found that certain people have an increased risk for obesity, for example, minority ethnic children [45], 16-year-old girls with stress-related eating [5], truck drivers with insufficient sleep and older than 40 years [46], adults at least 22 years old with abnormal blood pressure [47], women (60–80 years old) or men (55–80 years old) at high cardiovascular risk but without previously documented history of cardiovascular disease [48], and infants associated with maternal obesity [49].

The present paper contributes to elucidating the role of obesogenic environmental factors by proposing a possible pathway linking obesogenic environmental determinants of diet and obesity prevention and treatment. Potential relevant factors such as political policy and regulation [50] and mental status to diet [44] have also been evaluated because of the complexity of the task. The objective of addressing the obesity epidemic was to employ strategies to curtail sugar use, restrict marketing efforts, and increase the availability of healthy food.

As the number of published obesogenic research grows, we hope to see direct effects on health and wellbeing and

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indirect benefits from increased support from related research. There are no large pediatric randomized trials and very few published papers in treatment of obesity. One of the limitations in this study was the publication bias in the sampled database. There was substantial heterogeneity among studies with respect to study samples, interventions, and outcomes. There is a need to develop refined tools and indicators to monitor environmental changes on the basis of the amount of data available in the scientific literature and the potential for intervention.

There is an improvement in the following area. First, the research focus on the measurement and evaluation of the obesogenic environment has been led by Western countries. Further study in the rest of the world with highly dense populations should be conducted for comparison in the global obesogenic environment.

Second, the solutions for ensuring individuals' responsibility in achieving and maintaining a healthy weight from early life throughout their school years and into adulthood remain unclear. The relatively weak empirical evidence implies the absence of causal relationships between environmental factors and individuals' diet. A longitudinal approach would provide more robust evidence concerning the links among media use, diet behavior, and obesity prevention and treatment.

Third, a lack of appropriate research design exists in the previous studies, which may have reduced the validity of the results. Abundant previous review studies have used indirect methods to assess the environment and excluded nonhuman subjects from their analyses [20]. Future studies should adopt a rigorous methodological design to assist in providing strong evidence for the complex association of obesogenic environmental determinants of diet.

To determine the casual relations between food intake and the obesogenic environment, the influence of interactive, social, mass, or community-based media should be examined. Raising public awareness of obesogenic environmental determinants of unhealthy diet is a costly and complex endeavor. As public awareness campaigns become increasingly sophisticated, additional studies would help to evaluate the success of campaigns, tracking changes in attitudes and behaviors of people with obesity.

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Challenges of Comparing Medication eHealth Services in the Nordic Countries

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***Abstract*— A prescription and medication service that is optimised to protect against unnecessary harm is an essential component of a safer healthcare system. To this means, the Nordic countries have put considerable efforts in digitizing their prescription and dispensing processes and making medication eHealth services available for clinicians, pharmacists and patients. As these e-services are being established and applied, there is a need to monitor and learn from their use. This paper reports from a sub-study of a larger activity on developing indicators for monitoring eHealth services in the Nordic countries. We describe different medication eHealth services and compare their availabiliy to professionals and patients in the Nordic countries. We found that an ePrescription service is available for clinicians and patients in all Nordic countries, but services that enable renewal or viewing of prescriptions by patients are not commonly available yet. A major challenge when comparing medication eHealth services is the fact that definitions of indicators vary between countries.**

Keywords- *Medication data, ePrescription, medication list, indicator*

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I. INTRODUCTION

Access to information about medication is crucial for high quality healthcare and patient safety [1]. Viewing an up-to-date list of current medications is a prerequisite when prescribing a new drug, administering medications or assessing potential side effects, decreasing errors when dispensing medications, for preventing medication errors and adverse drug events in the healthcare system [2], as well as for control of financial aspects for prescription products. From the patient's perspective, having an updated list of their medications is an effective means of ensuring that the health professionals they encounter on their path through the health system are kept aware of some of the most important aspects of their health.

Most nations now devote large resources in digitizing their healthcare systems and in building eHealth services for care professionals and patients. As such services have been built and taken into use, there is a need for monitoring and assessing the use of such services for mutual learning and improvement [3]. What characterizes eHealth services that are available at a national level in the Nordic countries and how are these being used? These are some of the questions that a Nordic eHealth Research Network (NeRN) has posed in an inter-Nordic collaboration on developing indicators for monitoring eHealth. NeRN is a research group [4] reporting to the eHealth group of the Nordic Council of Ministers, and is working with development, testing and assessment of a common set of indicators for monitoring eHealth in the Nordic countries (Finland, Sweden, Norway, Iceland and Denmark), plus Greenland, the Faroe Islands and Åland.

Medication eHealth services include different e-services related to medication management for patients, pharmacists and care professionals. A central element of medication eHealth services is the electronic recording of prescriptions. The representations of prescriptions can be described as involving three different characteristics: Prescription as assigning a *right,* Prescription as a *withdrawal action* (Dispensing) and Prescription as an *administered action*, i.e., the patient has taken the medicine. As such, the *decision to medicate, prescribing*, *dispensing* and *administering medicine,* are different aspects of a Medication eHealth service in form of an ePrescription service, see Figure 1. The decision to medicate is the first step, where the health professional decides when and how the patient should be medicated. ePrescribing is the electronic prescribing of medicine by a health professional to a patient and making it available to a pharmacy, where the medicine can be dispensed and picked up by the patient. The prescription is a signed artifact (document) that describes the medication and how it shall be taken. It gives the patient the right to pick up the medication at the pharmacy and use it according to the description. In hospital settings, the health pofessional does not need to perform the actual prescription and can go directly from deciding to medicate to dispensing of the medicine, as shown in Figure 1. Dispensing is the retrieval of a prescription and the dispensing of the medicine to the patient. The patient consequently administers the medication, when consuming it. The medication list is the overview of the medications that are prescribed and dispensed to the patient. An eMedication list service allows for both patients and professionals to access it.

Figure 1 illustrates worktasks related to medication, and the storage of data related to each task. The decision of medication is noted in a Medication Management System (MMS) by the health professional. Outside hospitals a prescription can be issued on a sheet of paper, telephoned to a pharmacy or sent as an electronic order to a prescription server, where it can be accessed by pharmacies. When a drug is dispensed at a hospital is will be documented in the MMS, if it is dispensed at a pharmacy,it will be documented in a pharmacy system – in some countries at a national level. Health professionals store information about the administration of drugs in a MMS.

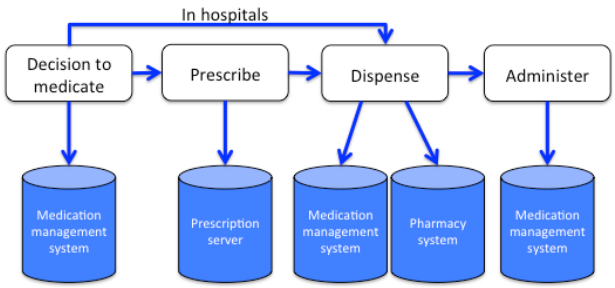

Figure 1. Overview of the process of a prescription from decision to medicate to administration of the medicine and where the data is stored in a medication eHealth service.

This paper addresses the issue of availability of *eHealth services related to medication* and offers a comparison of the availability for patients and healthcare professionals in the Nordic countries. The following research question guides the work presented in this paper:

What is the availability of ePrescription and eMedication list services in the Nordic countries?

The research question encompasses information from indicators identified by NeRN and is divided into following sub-questions for cross country comparison:

- Is an ePrescription service available?
- Does a national electronic medication list comprise prescribed and dispensed medication available?
- Is it possible for patients to renew their prescriptions electronically?
- Is it possible for patients to view their ePrescriptions?

Section II describes the methods used in the project. Section III offers a presentation of the results, and Section

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IV includes the discussion. Section V comprises concluding remarks.

II. METHODS

The indicators used in this study were derived from a rating survey performed in 2013, constructed on the basis of national survey questionnaires in the Nordic countries, an OECD model survey developed in 2012, eHealth policy analysis performed in 2013 and variables presented in the eHealth evaluation literature [5].

Data about the indicators for ePrescription and eMedication list services arise from discussions in a series of workshops with participants from all the Nordic countries arranged by the NeRN and a summary of the national survey questionnaires in the Nordic countries performed from 2010-2014 [6]. The results are presented as proportion of public healthcare organisations having the functionality within each of the Nordic countries.

III. RESULTS

When presenting the results, the sub-questions are addressed separately.

A. *Availability of a national ePrescription service*

The indicator is identical to an OECD indicator, but measured at a national level.

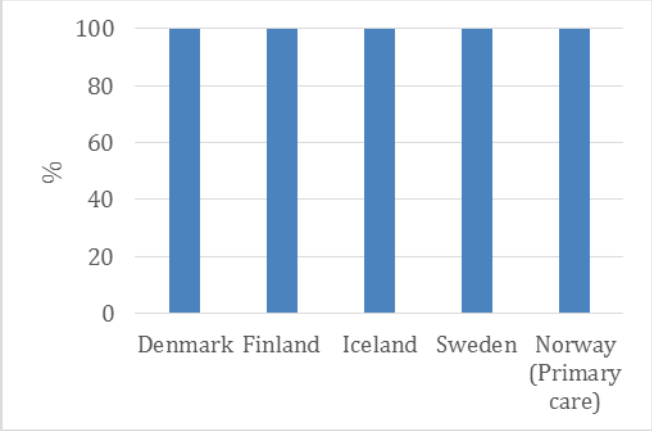

Figure 2. Availability of an ePrescription service.

Figure 2 shows that by the end of May, 2014, all the Nordic countries have a national ePrescription service in place. In Finland, Denmark, Iceland and Sweden, ePrescription is available at a national level, i.e., at all public hospitals within the country, for all GP´s, and at every pharmacy in the country. In Finland, the roll-out of ePresciption to the private sector is currently on its way. In Norway, all pharmacies, general practitioners, private specialists and emergency doctors, all (non-hospital) doctors allowed to prescribe drugs have access to ePrescription, and soon also dentists.

B. *Availability of a national electronic medication list of prescribed and dispensed medication*

The indicator, which is identical to the OECD indicator, measures the availability of information about medication that has been previously prescribed, or dispensed at another institution. However, the contents of this indicator vary in the Nordic countries. A national list of prescribed and dispensed medication is not necessarily the same as the patient´s current medication list, since for example the medication dispensed while admitted to a hospital or purchased without a prescription may not be included.

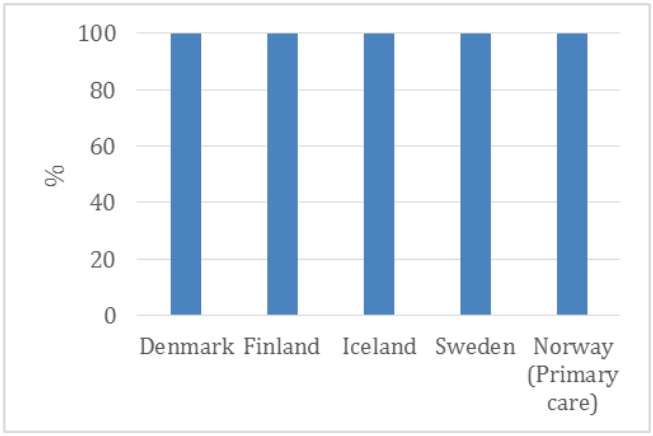

Figure 3. Availability of national electronic medication list.

Figure 3 shows the availability of national electronic medication lists in the Nordic countries. In Denmark, the medication list has been 100% available since 2010, including all types of prescriptions made outside hospitals as well as all medications dispensed both in and outside the hospital.

In Finland, the national prescription database shows prescribed and dispensed medication, but not those administered during hospital stay. Patients can preclude health professionals from accessing the data. The national list of prescriptions does not include prescriptions on paper or prescriptions that have been made by phone, nor prescriptions related to social care. From 2015, the national KANTA-system will generate a comprehensive list of current medication for the patient from the prescription database and data from individual electronic patient record (EPR) systems, including medication administered during hospital stay.

In Iceland, the availability of the national list of prescribed and dispensed medicine is 100%, since 2014, and includes all ePrescriptions, both prescribed and dispensed, as well as some paper and telephone prescriptions. All paper

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and telephone prescriptions will be available in 2015. As in Finland, the medication list does not include the medication administered during hospital stay.

In Norway, a national medication list is to be found in the “Kjernejournal” (Summary care record), and it may also be accessed via the national portal “helsenorge.no”. “Kjernejournal” is running as (in 2014) a pilot implementation in two regions. “Kjernejournal” will contain a list of the medicines the patient has been prescribed (both ePrescriptions and paper prescriptions) in Norwegian pharmacies. Medicines the patient purchased without a prescription, received at an emergency department, hospital / nursing home or purchased abroad will not appear. Prescriptions that have been dispensed are stored in the “Kjernejournal” for three years.

In Sweden, the list of medications that have been dispensed to the patient has been available since 2012. The patient decides if the doctor is allowed to see the information in the database. A consent is needed from the patient. Very few patients i.e., 3-4.000 patients out of 9 million actually choose to hide their information,

C. *Availability of electronic medication renewal*

This indicator shows the availability of services that enable electronic medication renewal at the national level. The indicator is identical to the OECD indicator.

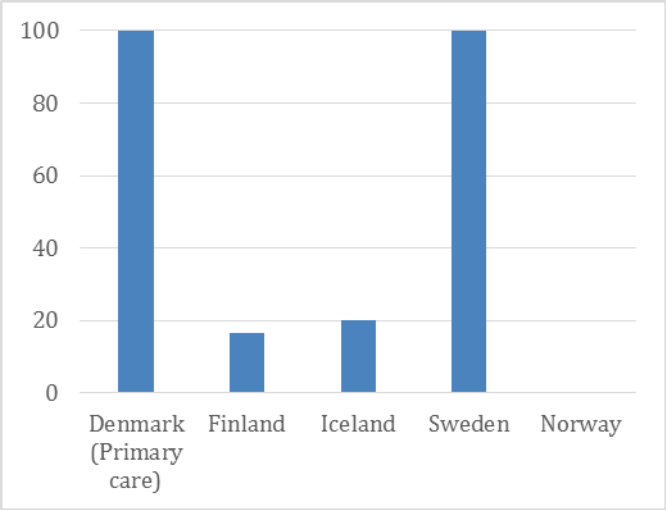

Figure 4. Availability of electronic medication renewal.

Figure 4 shows the availability of electronic medication renewal services in the Nordic countries. In Denmark, there is 100% availability of electronic medication renewal in primary care at a national level.

In Finland, this is currently an organizational activity. The patient needs to contact the pharmacy or primary health care centre to ask for a renewal, although many organizations provide an electronic web portal to mediate the request.

In Iceland, only a few health care institutions offered this service in 2014. However, this is currently being implemented and is expected to be at a national level before end of 2015.

In Norway, this service has not been established at the national level. General practitioners can offer service functionalities for patients depending on what portal provider they have chosen.

In Sweden, electronic medication renewal has been available since 2012 in the national service "My healthcare contacts (MVK)". MVK is a citizen web portal that enables secure communication between patient/ consumer/ customer and healthcare and longterm care. The patient can book and rebook appointments, renew prescriptions, order a copy of his patient record and in some county councils also access it.

D. *Availability of electronic viewing of patient’s own prescriptions*

This indicator concerns electronic services that enable patients to view their own medication data. We present data for services at a national level. The indicator is identical to the OECD indicator.

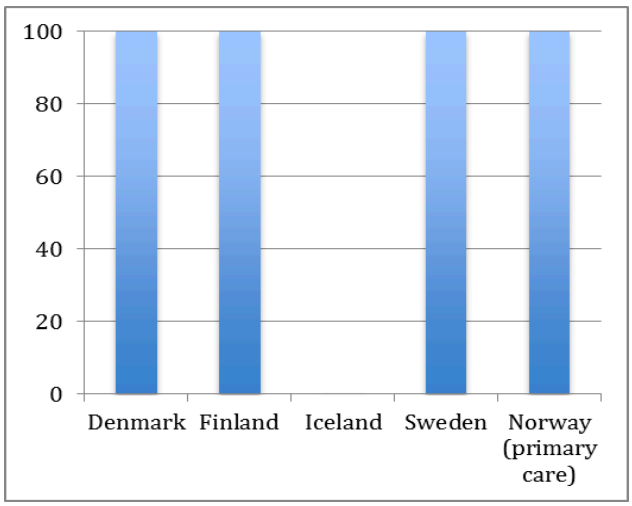

Figure 5. Availability of patients’ viewing electronically of own medication data

Figure 5 shows the availability of patients` viewing electronically of own medication data. In Denmark, patients have had the opportunity to view their own medication data covering the past two years since 2009. In the beginning, it only enabled viewing of prescriptions made outside hospitals. Since 2013, viewings of prescriptions made by hospital physicians have been included.

In Finland, all patients now have access to all prescriptions.

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This service did not exist in Iceland until November 2014. Currently, it only includes ePrescribed medications. However, plans are already underway to enhance these services to include also paper- and telephone prescribed medication.

Norway established this service in 2012-2013 via "My prescriptions" in helsenorge.no, but the service currently only enables viewing of the most recent prescriptions made by GPs.

In Sweden this service has been available since 2012 as a national service through "My healthcare contacts" (MVK).

Availability for patients viewing of medication data that (public/private sector) professionals have prescribed is a feature of national health information systems in the Nordic countries.

IV. DISCUSSION

The Nordic countries seem relatively homogeneous and comparable in terms of political system, infrastructure, culture, and educational, social- and healthcare systems; however providing comparable indicators from surveys across the Nordic countries involves a number of challenges. The samples of the survey varied: in Denmark, a representative sample of clinical end users participated whereas in the other countries leaders in health care institutions were approached. The survey questions were formulated in the language of the respective countries, and the time and frequency of the surveys varied. Detailed discussions of these differences settled most of the variance they introduced, and the results obtained on the medication issues were quite comparable.

Comparable e-services are the ePrescription services and the list of prescribed medicines, i.e., the proportion of public and/or private organizations where prescribed medicine outside the own organization, are available in all the Nordic countries. Although ePrescription is available it is still possible to issue prescriptions on paper or by telephoning the pharmacy. This proportion has not been measured but it is assumed that it is neglectable given the high number of prescriptions made electronically.

The ePrescription services are well established and mature in some countries, while in other countries they are still in a pilot phase. The availability of a National list of prescribed and dispensed medication has also by 2014 reached a level of saturation. In Denmark, this service has been available for some years. Although the service is available in all countries the architecture of the systems behind the services differ significantly, but a detailed analysis of these differences has not been targeted in this study. A special feature for patients to hide specific medications is available in all countries for similar ethical reasons.

The availability of an e-service to renew medication is not available in all countries. In Denmark, and Sweden, the service has been available for some years, however it is implemented in different ways. In Denmark, this service was implemented for all patients to use as part of the agreement between the general practitioners and the regions who pay them fee for service. In Sweden, the service is available to all citizens through a national portal. In other countries this service is available only through dedicated organizations.

The service that enables patients to view their own prescriptions has been implemented in all countries.

However, when going into detail about the content of the indicators, the NeRN group realized that characteristics of the indicators varied between the respective countries.

The availability of a national ePrescription service was saturated, but the content measured was different between the Nordic countries. In the definitions of the indicators, the fact whether the medication was prescribed, dispensed or administered was not clearly specified, or the data was not available because the question was not asked specifically in the surveys. It became apparent that the content of ePrescriptions and the measurements of them varied between the countries making detailed explanation in the presentation of the results necessary for each indicator and each country.

Another point which makes comparison difficult is the fact that ePrescription does not cover paper-based prescriptions per se, which are regulated in another way than electronic prescriptions. It has different consequences in the respective countries. In Denmark, for instance the paper-based prescriptions will be synchronized with the overview of the patient's own prescriptions once the medicine has been dispensed in a pharmacy. A related issue is that while ePrescriptions are 1-1 prescribed and dispensed medication, where the paper based prescription can hold more drugs on the same piece of paper.

The e-services in this paper more specifically referred to as *the medication eHealth service*, may have different scopes, i.e., intended coverage area. While some e-services are accessible at a national level, others are either limited geographically to a regional level, administratively to the hospitals or the organizations, or to specific roles, for example to healthcare professionals and not to patients. The focus in this study is the availability of medication eHealth services at a national level and availability at a more granular level was therefore not presented.

V. CONCLUSION

The study showed that the availability of patients' prescription information and ePrescriptions made available to any pharmacy is realized via the national ePrescription systems in each Nordic country. Moreover, the availability

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of medication renewal requests as well as the availability of electronic viewing of patients' own prescriptions is comprehensive on national level in some countries (Sweden, Denmark and Iceland). Patients' access to view their prescription data electronically is also broad. However, the NeRN findings demonstrated that the services are realized differently in the respective countries and also definitions of indicators vary between countries hampering comparison.

ACKNOWLEDGMENT

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Brain Activity Estimation with Precise Motor Measurements of Visual Synchronization Task of Hands

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***Abstract*— Visual synchronization tasks are difficult. We need intensive brain activity for completing visual synchronization tasks. Recently, we can measure the precise movement of a human with cheap and easy to use sensors. We propose a method to estimate the total brain activity using the precise measurement of the motor of a human body. This paper measures the movement of hands of a human synchronizing the example movement presented on a display. With the Fourier analysis of the movements, we propose to measure the synchronization of hands. This measure helps to detect a small change of the brain activity that might be indicative of brain diseases. As a result, the measure helps to detect a small symptom of brain diseases.**

Keywords-motor measurement; cerebral dysfunction.

I. INTRODUCTION

There are many motor tasks that measure the abilities of motor functions of a human. They are the Purdue pegboard task, a seal affixation task, a tray carrying task, etc. [1][2][3]. These tasks estimate the ability of a motor function of a human based on the results of the tasks. There is no observation of the process of the tasks.

There are also some synchronization tasks used to measure human abilities. For example, they are synchronization of finger taps with periodically flashing visual stimuli and synchronization with an auditory metronome. In these tasks, the timing between the stimuli and the tapping is measured. There is no observation of the process of the tapping [4][5][6][7][8][9][10].

Recently, many cheap and easy measurement methods for the movements of a human body have been developed. For instance, some of these sensors include Kinect sensor, and Leap motion sensor [11][12]. There are many applications that use those sensors for controlling computers. For instance, there are many video games that use those sensors for controlling an avatar in the games [13].

Many researchers report that many kinds of brain disorder affect motor functions. In this paper, we propose a method measuring motor functions that are reflections of many brain functions. If we can measure the motor functions that reflect all the brain functions, the measurement reflects the total brain activity. As a result, in case of any brain disorder, the measurement of motor functions will reveal some symptom about the disorder.

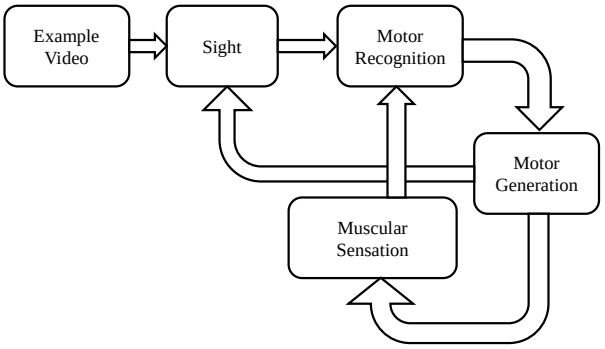

Figure 1. Relations among brain functions for performing the proposed synchronization task.

The human hands are the parts of a body that can make the most complex movements. This paper proposes a method that measures the precise movements of hands synchronizing the movements of hands on a display. The synchronization needs visual perception of the displayed hands' images and precise control of the arm muscles.

We can now precisely measure the movement of hands. This paper proposes a new synchronization task and the evaluation method. The resulting measure is very sensitive. With this measure, we can observe the developments of the motor function and infer on brain activity.

First, we discuss the synchronized hands' movements with visual presentation. Then, this paper proposes the outline of the proposed observation system for visual synchronization of hands' motions. Next, we show our implementation of the observation system. Then, we discuss the brain function estimation method using the measured visual synchronization. Next, we show our experimental results and conclude this work.

II. VISUAL SYNCHRONIZATION TASK

There are many motor tasks that intend to measure the motor function of a human. However, most of these tasks measure the results of the tasks. There are some tasks that measure the synchronization between a finger tap and stimuli. With human observations, it is difficult to measure the process of synchronizing movements. Now, we can use a Kinect sensor and a Leap Motion sensor. Those sensors

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measure the three-dimensional movements of a human body. With these sensors, we can measure the precise movements of a human body.

We can synchronize our movements with each other. For instance, in playing a dance, dancers can synchronize their movements with each other. A synchronization of movement is more difficult work than a simple imitation of movement. To generate synchronized movements, we need to observe the motion to be synchronized. We need to generate the motion to be similar to the motion synchronized. We need to observe the generated motion synchronizing the original motion. We need to estimate the divergence between the original motion synchronized and the motion synchronizing the original motion. We need to control the speed of the motion synchronizing. These functions make the feedback loop. However, for compensating our brain's processing delay, we need to estimate the delay itself and make feedforward.

This processing loop is shown in Fig. 1. For estimating the total brain function, we need to include all the functions of a brain. The visual synchronization task includes vision and motor functions. The vision includes not only the static sight, but also the dynamic sight.

The visual synchronization is more difficult than audio synchronization. So, we observe the wider brain functions with the visual synchronization tasks than the audio synchronization tasks.

Our proposed visual synchronization task is the synchronization between the position of stimuli on a display and the position of hands. Our synchronization task is not the synchronization between the timing of stimuli and the timing of action. The measurement of timing is only one scalar value. In our proposed synchronization task, the measurements of positions between the stimuli and the hands are the sequence of a triple of the position of the stimuli and the ones of both hands.

III. VISUAL SYNCHRONIZATION OBSERVATION SYSTEM

Classical synchronization tasks measure the timing between the result of action and the stimuli. We observe the process of synchronization between the stimuli and the motion.

A. Stimuli

For the motor task, we select the rotation of both hands. Rotation is a difficult movement of a hand. For analyzing the synchronization easily, we make the stimuli follow a precise sine curve. If stimuli form a precise sine curve, we easily evaluate the observed motion comparing with the sine curve. Fig. 2 shows the sequence of stimuli. The images are proposed on display with a constant interval from top to bottom. And then, they are proposed from bottom to top. These two sequences make one cycle of the stimuli of hands' motion. In the stimuli images, the right hand and the left hand are the same. The right one is the mirror image of the left one.

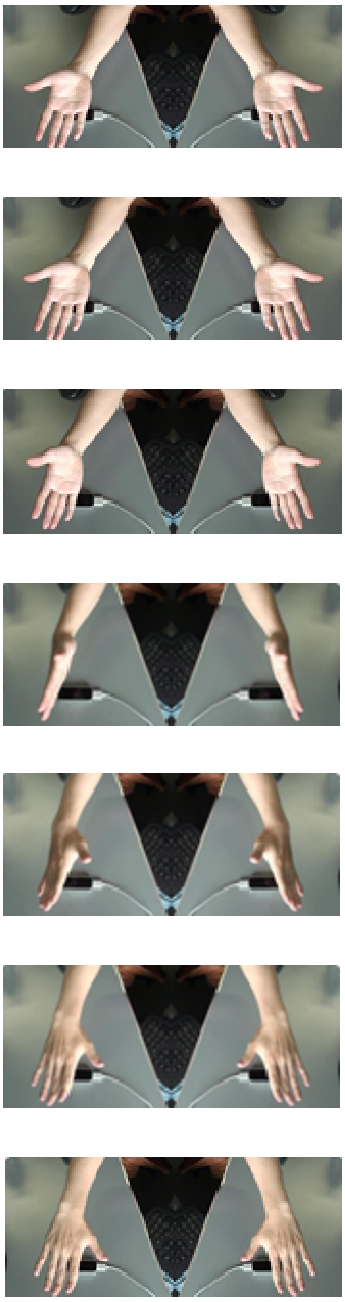

Figure 2. Stimuli Images.

B. Stimuli generation

Our stimuli are a displayed video of both hands' rotation. However, in a normal video, it is difficult to control precisely the motion of hands in the video to follow the sine curve. It is also difficult to evaluate the synchronization between the stimuli and the motions of hands. We propose the stimuli generation method that displays a proper image at the precise timing.

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C. Hands' rotation measurement

We use the Leap motion sensor for measuring the position and the pose of both hands [12]. With the Leap motion sensor, the measurements are not performed at a fixed interval. However, the Leap motion sensor measures the position and the pose of hands about 120 times within a second. We determine the precise position and pose at every 1/100 S with interpolating linearly between two adjacent measurements.

D. Synchronization measure

We define the synchronization measure using FFT (Fast Fourier Transform) results of the estimated poses of both hands in each cycle. If a subject makes complete synchronization to the stimuli, the resulting pose of both hands follow a complete sine curve. As a result, at every cycle of the rotation of hands, the result of FFT has a zero value at the second term or higher terms. We define the measure as (1). This measure increases with the amount of the difference from ideal sine curve.

$$(\sum_{x=2}^{t/4} m_x)/m_1 \quad (1)$$

In (1), t is the number of terms. m_x is the absolute value of the x-th term of the result of FFT. m_1 is the power of the lowest frequency. This represents a one cycle of a hand's rotation. If the rotation of a hand follows the stimuli images precisely, the m_1 carries all powers of the hand's rotation. Other terms carry no power. In the case, the measure in (1) is 0.

m_0 is a value that represents the average of poses. This is not included in (1). As a result, this measure does not depend the absolute poses of hands.

We call this measure as Non-Smoothness-Measure (NSM). This measure may span from 0 to infinite.

Our proposed system observes two hands. So at every cycle, we have two NSMs.

IV. Implementation of the Proposed Sytem that Measures Visual Synchronization

A. System Overview

The visual synchronization measurement system has two major parts. One part displays the intended hand's motion, and the other part measures the position and the pose of hands with the Leap motion sensor. These two main parts must work smoothly. The stimuli must be updated at precise timing. The measurements of the position and the pose of hands must continue without interruption. To perform these requirements, our proposed implementation has two main processes. One process works to display stimuli images, and the other records the position and the pose of hands.

We use Python and Pyglet for implementing the system [14]. Pyglet is an object-oriented programming interface for developing games and other visually-rich applications [15].

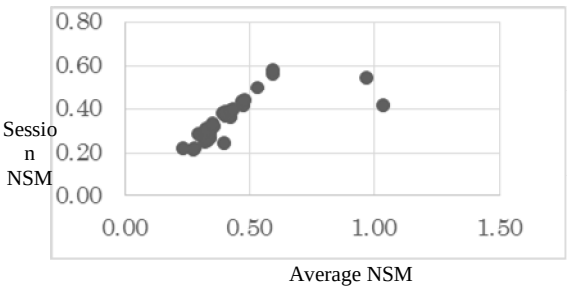

Figure 3. The distribution of the pairs of session NSM and average NSM.

B. Stimuli Image

For creating stimuli images, we recorded the hands' rotation images with the measured hands' positions and poses. Then, we selected the images that fit for the sine curve. The selected sequence of hands' images fits for the sine curve.

C. Stimuli Image Presentation

With the progress of time, our proposed system selects the most proper image and proposes on a display. This stimuli image presentation takes a one process. There is no intervention from other processes, for instance, hands' rotations measurement.

D. Hands' Rotations Measurement

We use the Leap-Motion-Sensor for measuring the hands poses. To measure the pose of hands, we can use attached type sensors. The attached type sensors have enough accuracy and measuring speed. However, we need longer setup time. This prevents the easy and fast measurement. The sensor measures the pose of hands at each 1/100 S. The measurement includes the positions and the poses of both hands. The measured record has about 700 KB in 25 second. The system must record all data without loss. This measuring shares a one process. As a result, there is no intervention from the Stimuli image presentation. The sensor works in enough speed.

V. Experiments and Discussions

We made two types of experiments. One experiment elucidates the distributions among normal people. The other does the changes on a person.

A. Experiments Setup

From the pre-experiments, the speed of the hands' rotation is best at one cycle per second. Subjects need about 10 S to synchronize their movements of hands to the proposed motion images. As a result, one session of an experiment needs at least 11 S. For getting reliable results, we decide that the length of a session is 25 cycles of rotations. This means that one session needs 25 S. Before starting a session, we instruct a subject to synchronize their hands to the displayed hands' images.

B. Session Non-Smoothness Measure

At each session, we have 25 cycles' measurements. As a result, we have 25 pairs of NSMs (Non-Smoothness Measure). Our observation shows that a subject needs about 10 S for synchronizing to the proposed images. So, we

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exclude first 10 cycles. As a result, at each session, we have a sequence of 15 pairs of NSMs.

At a single cycle, there may be some distributions. We select three continuous cycles' average of NSMs to evaluate the synchronization. At each session, we select the minimum of three continuous cycles' averages of NSMs as the NSM for the session at each hand. The NSM is computed at each hand. We have two points that the average of continuous three NSMs is the smallest. At each point, we have a pair of the averages of continuous NSMs. They are the average NSMs of the left and right hands. As a result, we have four average NSMs.

A pair has the average NSM at left hand and the average NSM at right hand, when the average NSM of the left hand is minimum. And, another pair has the average NSM at left hand and the average NSM at right hand, when the average NSM of the right hand is minimum. From the four NSMs, we decide that the session's NSM is the minimum of all four NSMs.

TABLE I. EXPERIMENTAL RESULTS OF NORMAL PEOPLE.

	Cycle number where the NSM is the smallest.		**NSMs at the cycle where the Right hand NSM is the small**		**NSMs at the cycle where the left hand NSM is the small**		**Session NSM**	**Average NSM**	**Average NSM|-Session NSM**
Subject	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**			
M 22	7	8	0.31	0.36	0.32	0.32	0.31	0.33	0.02
M 24	1	5	0.24	0.83	0.26	0.24	0.24	0.40	0.15
M 24	7	1	0.37	0.33	0.40	0.32	0.32	0.35	0.03
M 27	2	6	0.31	0.36	0.32	0.29	0.29	0.32	0.03
M 20	2	2	0.43	0.51	0.43	0.51	0.43	0.47	0.04
M 20	0	9	0.44	0.51	0.47	0.50	0.44	0.48	0.04
M 24	8	3	0.31	0.32	0.39	0.27	0.27	0.32	0.06
M 27	11	11	0.29	0.39	0.29	0.39	0.29	0.34	0.05
M 19	9	0	0.39	0.38	0.47	0.37	0.37	0.40	0.04
M 19	4	4	0.62	0.56	0.62	0.56	0.56	0.59	0.03
F 19	8	9	0.39	0.44	0.44	0.42	0.39	0.42	0.03
F 19	9	7	0.43	0.43	0.47	0.40	0.40	0.43	0.04
M 27	2	10	0.22	0.35	0.28	0.27	0.22	0.28	0.06
F 20	1	1	0.22	0.25	0.22	0.25	0.22	0.23	0.01
M 21	6	0	0.29	0.35	0.31	0.33	0.29	0.32	0.03
M 21	2	0	0.26	0.41	0.34	0.32	0.26	0.33	0.07
M 20	1	2	0.27	0.43	0.29	0.39	0.27	0.34	0.08
M 20	8	8	0.38	0.41	0.38	0.41	0.38	0.39	0.01
F 21	1	2	0.29	0.31	0.29	0.30	0.29	0.30	0.01
F 21	8	0	0.34	0.32	0.38	0.25	0.25	0.32	0.07
M 20	7	6	0.21	0.35	0.23	0.30	0.21	0.27	0.06
M 20	8	8	0.30	0.37	0.30	0.37	0.30	0.33	0.03
M 20	0	0	0.33	0.37	0.33	0.37	0.33	0.35	0.02
M 20	7	8	0.30	0.34	0.34	0.31	0.30	0.32	0.02
M 18	10	9	0.46	0.39	0.49	0.36	0.36	0.42	0.06
M 18	0	6	0.55	1.62	1.13	0.56	0.55	0.97	0.42
M 20	2	2	0.58	0.60	0.58	0.60	0.58	0.59	0.01
M 20	3	5	0.53	0.53	0.57	0.50	0.50	0.53	0.03
M 19	5	5	0.42	0.39	0.42	0.39	0.39	0.40	0.01
M 19	10	10	0.54	0.41	0.54	0.41	0.41	0.48	0.06
M 25	6	0	1.06	1.17	1.49	0.42	0.42	1.03	0.62
Average	5.00	4.74	0.39	0.48	0.44	0.38	0.35	0.42	0.072
Normal distribution	3.45	3.58	0.16	0.27	0.25	0.10	0.10	0.17	0.123
M 58	0	0	2.43	2.43	2.43	2.43	2.43	2.43	0.0

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C. Distribution on Normal adult people

There are 19 subjects whose ages span from 18 years old to 27 years old. They include three females.

Fig. 3 shows the relation between the session NSM and the average NSM. In many cases, the average NSM and the session NSM have linear relation.

Each subject tries two sessions. There are 38 sessions. However, at some sessions rotation measurements fail. As a result, we have 31 valid sessions of normal subjects. Table I shows 31 valid sessions' NSMs and one subject who declares weakness in sport. In the subject column, M represents a male. The number is the age. The 'Right' is the position where the right hand's NSM is minimum. The 'Left' is the position where the left hand's NSM is minimum. The 'Right/R' stands for the NSM of the right hand at the position where the right hand's NSM is minimum. The 'Left/R' stands for the NSM of the left hand at the position where the right hand's NSM is minimum. The 'Right/L' and the 'Left/L' do respectively.

The average is 0.35. The normal distribution is 0.10. The distribution is small. The range of NSM under 1.0 include over 0.9999999999. In most of the sessions, the session NSM and the average NSM are nearly same. However, at two sessions, they are different. We can conclude that the session NSM and the average NSM are nearly same in a normal person. If the average NSM and the session NSM are different, there may be a problem at the measurement or the subject.

D. Subject weak in sports

We have one subject who declares his weakness in sports. The last raw in Table I shows NSM of a subject who is weak in sports. The session NSM is very large, and it differs 21σ from the average of NSMs of the normal people.

E. Personal diurnal variation

With two subjects, we observe the diurnal variations. They are 25 years old and 27 years-old males. In this experiment, we measure the performance at every 30-minute interval from 9:00 to 18:00. Table II and Table III show the experimental results. There are some missing data. Figure 3 and Fig. 4 shows the session NSMs in time series. In the figures, the linear estimation form and R^2 are shown. Their linear approximation shows a little increase in the time course. This may show the accumulation of fatigue. However, the R^2 is lower than 0.5. The number of experiments is not large enough for concluding. In the afternoon, the two subjects show a large increase of the NMS. At the time, they may be a little sleepy. At the time, the brain activity may be a little lower than a normal state.

The averages are 0.30 and 0.31. The normal distributions are 0.07 and 0.04. The diurnal variation

TABLE II. DIURNAL VARIATION

Time	Right	Left	Right/ R	Left/R	Right/ L	Left/L	Session NSM
9	9	2	0.21	0.30	0.27	0.26	0.21
9.5	-	-	-	-	-	-	-
10	9	4	0.26	0.31	0.34	0.30	0.26
10.5	9	9	0.29	0.29	0.29	0.29	0.29
11	4	2	0.39	0.31	0.42	0.27	0.27
11.5	5	0	0.28	0.73	0.33	0.36	0.28
12	0	9	0.35	0.46	0.45	0.38	0.35
12.5	-	-	-	-	-	-	-
13	6	3	0.29	0.39	0.32	0.32	0.29
13.5	1	0	0.30	0.35	0.31	0.32	0.30
14	4	2	0.72	0.65	1.54	0.37	0.37
14.5	4	5	0.32	0.35	0.33	0.33	0.32
15	1	0	0.31	0.36	0.34	0.35	0.31
15.5	2	7	0.31	0.87	0.33	0.36	0.31
16	3	3	0.31	0.36	0.31	0.36	0.31
16.5	8	4	0.32	0.43	0.46	0.37	0.32
17	0	7	0.31	0.42	0.38	0.42	0.31
17.5	-	-	-	-	-	-	-
18	9	7	0.30	0.40	0.35	0.34	0.30
Average			0.33	0.44	0.42	0.34	0.30
Normal distribution			0.11	0.16	0.29	0.04	0.04

TABLE III. DIURNAL VARIATION

Time	Right	Left	Right/ R	Left/R	Right/ L	Left/L	Session NSM
9	0	6	0.27	0.32	0.38	0.27	0.27
9.5	-	-	-	-	-	-	-
10.5	7	0	0.31	0.34	0.39	0.32	0.31
11	3	1	0.25	0.38	0.28	0.31	0.25
11.5	0	0	0.32	0.36	0.32	0.36	0.32
12	8	7	0.22	0.40	0.23	0.33	0.22
12.5	-	-	-	-	-	-	-
13	10	10	0.46	0.45	0.46	0.45	0.45
13.5	11	11	0.49	0.46	0.49	0.46	0.46
14	1	1	0.30	0.27	0.30	0.27	0.27
14.5	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-
15.5	3	5	0.33	0.28	0.34	0.27	0.27
16	7	7	0.90	1.10	0.90	1.10	0.90
16.5	8	8	0.32	0.28	0.32	0.28	0.28
17	8	4	0.33	0.91	0.34	0.34	0.33
17.5	6	6	0.32	0.34	0.32	0.34	0.32
18	1	12	0.30	0.37	0.40	0.32	0.30
Average			0.36	0.44	0.38	0.38	0.31
Normal distribution			0.16	0.23	0.15	0.20	0.07

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of a person is smaller than the inter-individual variation. As a result, we have the reliable NSM of a person with a small number of trials.

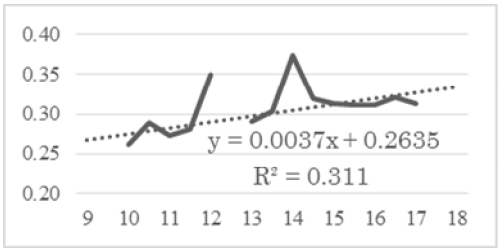

Figure 4. Personal diurnal variation of subject 1.

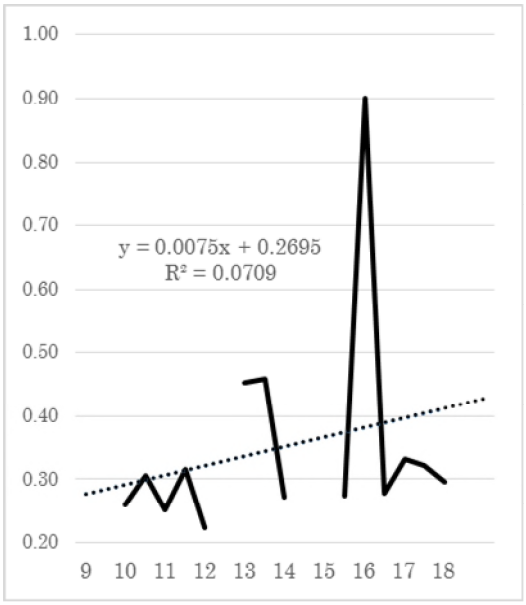

Figure 5. Personal diurnal variation of subject 2.

F. Discussions about Brain Activity

In subsection D, the NSMs of healthy peoples converges on 0.35. In subsection E, the diurnal variation is smaller than the inter-individual variation.

If the NSM is large, there is a problem of the motor functions. The cause of the problem may not only be the disorder about brain functions, but also be the disorder about nerves, muscles, etc. Our proposed method cannot find the cause of the motor disorder. However, if there is no change in the functions about nerves, muscles, etc., the increase of the NSM shows the disorder about the brain.

If we have the NSMs about a person in a long term, the increase of the NSM shows the new disorder about brain function.

VI. CONCLUSION

The pair of the proposed synchronization task and the evaluating method enable to measure the precise performance of the motor function of hands. The task is easy to perform. For instance, it needs merely 25 S. The proposed Non-Smoothness Measure has enough power of discrimination between normal people and people that has some motor problems.

This NSM can be used for evaluate the development of the motor function of children. This NSM detects very small disorder of the brain activity. For normal people, the NSMs concentrate on a small range. The personal diurnal variation is small enough for detecting small disorder of brain activity. We will perform larger scale experiments in the next step.

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A Finger Movement Evaluation Device to Monitor the Use of Paretic Hand During Daily Life Activities

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Abstract— Hand movement tracking devices are important to monitor impaired hand function during daily activities. The study presented in this paper investigates the feasibility of using a hand glove device to monitor the use of paretic hand in daily life. A Finger Movement Evaluation Device (FMED) was developed for this purpose and it was tested on six stroke subjects who used it for two days. FMED records the flexion angle of two metacarpophalangeal (MCP) joints (for example, index and middle MCP joints). A questionnaire was used to evaluate subjects' acceptance of FMED. Data collected by FMED were analyzed to calculate the ratio of finger movement episodes during the day and amount of movement as a sum of individual movement episodes. Results showed a high satisfaction of patients and the ability to acquire quantitative information about the quality of movement while using the device; these results concluded that FMED is a promising tool to monitor the use of impaired hand in real life whether as a regular routine test or as part of a home based therapy set up.

Keywords- hand glove devices; movement impairmemt; stroke

I. INTRODUCTION

Stroke is the major cause of neurological disability all over the world [1]. However, upper extremity (UE) motor impairment, specifically hand paresis, is the most disabling and persisting residual impairment after this event [2], and it is evident that it limits basic activities of daily living [3]. For this reason, the role of stroke rehabilitation is to promote the independence in daily life activities [4]. Moreover, the use of outcome measures (OMs) in neurological physical therapy is essential to evaluate the improvement of function during rehabilitation [5]. So, an essential issue in the assessment after stroke is to determine how much the impairment of upper extremity is the source of loss of function, and if the selected rehabilitation intervention improves the activities of daily life of stroke survivors.

Numerous standardized clinical measures are available for clinicians to evaluate UE function after stroke. Yet, these measures are rarely used in clinical practice because of time constraints, high level of difficulty, lack of equipment, and lack of knowledge regarding OMs [6]. Besides, most of these measures do not collect information about the use of UE in the Activities of Daily Living (ADLs) and they do not provide clinicians with quantitative and objective information about patients' use of impaired limb during the day [7]; thus, they do not reflect how the patients interact in their daily life and their real world [8]. The use of assessment tools at home and community is essential to evaluate the UE function during daily activities in order to improve therapeutic intervention and avoid having patients stop using the impaired limb due to pain or absence of confidence and eventually losing the ability to use it due to the learned non-use phenomena [9].

Wearable measurement devices and home monitoring devices provide clinicians with additional assessment opportunities like collecting hand posture and movement data as individuals perform daily activities outside the clinic [10]. Despite their importance in measuring fingers' range of motion during dynamic tasks [11], different limitations exist; they are expensive, heavy and uncomfortable to be worn in daily life outside the clinic [12, 13] , and do not provide long term monitoring [12].

Preliminary research in the area of hand glove devices has focused primarily on testing protocols that evaluated glove devices characteristics [10-12, 14-17] and none of them has explored the use of these devices to monitor the impaired UE function during daily life.

This article describes the design of a low cost device for the assessment of finger's movement during daily activities. Section II describes the device design and implementation, Section III describes the feasibility study

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methodology. Sections IV elaborates on the results and discussion, followed by conclusion in Section V.

II. METHODS

A. Finger Movement Evaluation Device (FMED)

The Finger Movement Evaluation Device (FMED) was designed to act as an offline electronic goniometer that measures finger flexion angle of 2 joints simultaneously. It includes two bending sensors (SpectraSymbol®, UT, USA) that can be placed on two fingers' MCP joints (for example index and middle fingers) at a time using Velcro™. Only 2 joints are tracked in order to reduce the cost of the device letting the user focus on two fingers at a time with the flexibility in choosing which joints to track.

Figure 1 illustrates the main parts of the device. A voltage regulator circuit was implemented to down regulate the power from a 12V (6500 mAh) rechargeable battery to 5V. A dc-dc converter was implemented before the voltage regulator to convert 12V to 7V in order to avoid too much heat dissipation in case of using the voltage regulator to down-regulate from 12 to 5V. A charged battery (12V, 6500 mAh) can power the device for more than 48 hours.

The microcontroller (ATmega2560) reads input from the bending sensors through a voltage divider signal conditioning circuit. This is a low-power complementary metal–oxide–semiconductor (CMOS) 8-bit microcontroller that supports a real Read-While-Write Programming mechanism. The microcontroller processes the data, and saves the values of each joint on an SD card in real time. The raw data are saved on the SD (Secured Digital) card in addition to the fractionation angle (difference in angle between the two joints). This device also gives patients a real-time feedback of their movement using a set of light emitting diodes (LEDs) indicating the level of fingers movement flexion with increments of 10º (10º, 20º, 30º, 40º, 50º, 60º, 70º, 80º, 90º) and fractionation with increments of 5º (5º, 10º, 15º, 20º, 25º). The main electronics of the device was chosen to be surface mounted in order to reduce the size and weight of the device. FMED weighs 1.3 kg with battery. Figure 2 shows FMED worn by a volunteer.

B. Collected Data

As mentioned in the last section, the device saves the values of the variation of angles for sensors 1 and 2 (for example, index and middle finger flexion angles) and the individuation (difference between angles recorded by sensor 1 and sensor 2) versus time. A customized Matlab® algorithm was written to process these data. The first processing step was to calculate differences between adjacent elements of the dataset in order to detect movement episodes (change in flexion and individual angles). A threshold of 2º was used to count the episodes of movement (flexion angle exceeding a 2º predefined threshold). The ration of counted samples over whole dataset provided the Ratio of Movement (RaOM) values of each finger.

The other parameter that was calculated is related to the mean of difference in the angle between the two fingers (individual finger movement). Episodes or consecutive samples where there was a difference in flexion between index and middle fingers were reported. These episodes were counted to derive the Integral of Individuated Movement (IIM) episodes value. This value indicates how much the subject was moving the index finger independent of the middle finger and vice versa. IIM reflects how much the patient is capable of controlling one finger independent of the other during executing a functional task. The parameters (RaOM and IIM) calculated based on the recorded data were used as the main outcomes of FMED to effectively quantify the amount of movement during the day.

III. FEASIBILITY STUDY

A. Recruitment

Subjects with stroke were recruited from multiple rehabilitation centers in Beirut, Lebanon. Six individuals, with a clinical diagnosis of stroke in the chronic phase (3 males and 3 females, mean age 49.33±8.1, > 6 months post-stroke) participated in the study.

Subjects were included because they had residual upper extremity impairments (Upper extremity Fugl-Meyer [FM] scores, with a range of (45-56)/66; and with mean flexion fingers ROM ± 1 standard deviation: 73.3 ± 7.4 degrees).

Inclusion criteria was chosen to give a nearly homogenous group of subjects between 40-60 years, with similar representation of both sexes, and approximately same degree of hand function deficit. The participants signed informed consents approved by the Lebanese University, school of health ethical review board.

B. Feasibility Testing Protocol

The first step in the procedure was to meet the subjects to inform them about the study, the device, and train them to use it at home. Patients wore the glove at home for two days. In the first day, they were requested to wear the glove in the impaired hand and use it like they usually do

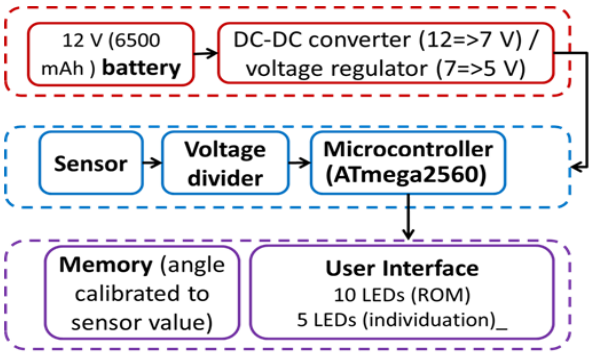

Figure 1: Main components of FMED

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TABLE I. USER FEEDBACK QUESTIONNAIRE RESULTS

Question	Average	SD	t-value	p-value
I felt comfortable as the glove was put on	6.33	0.82	7.0	
I did not feel like my fingers were put into any uncomfortable position as the glove was put on	6.33	1.21	4.7	
I felt any restriction to movement with this glove is similar to other gloves I have worn	6.67	0.52	12.6	
I would feel comfortable wearing this glove in public	6.67	0.52	12.6	
I felt comfortable performing the activities in this study	6.50	0.84	7.3	
I feel I can do most of my daily activities (except those involving water) while wearing this glove	6.67	0.52	12.6	
The glove did not feel too tight (it did not make my hands or fingers tingle)	6.83	0.41	17.0	< 0.001
I feel like I can bend my fingers just like I can without wearing the glove	6.83	0.41	17.0	
The glove did not feel too hot or too cold	6.50	1.22	5.0	
I did not feel like my fingers were put into any uncomfortable position as the glove was removed	6.33	1.03	5.5	
I felt comfortable as the glove was removed	6.33	0.82	7.0	
Average	6.55	0.20		

during daily activities, and remove it before sleeping. In the second day morning, they received a call from the study personnel and they were asked to wear the glove and to do specific activities by their impaired hand during the day in addition to their daily routine. The research team did not supervise the patient at home; however, the device recorded the data of movement of the patient on the SD card. The following day, FMED was collected from subjects, each subject filled the user feedback questionnaire, and the data saved on the SD card were collected for offline analysis.

Acceptance of the device and patient's feedback was evaluated based on a user feedback questionnaire [12], and an open-ended discussion, performed after using the device for two days. The participants were supposed to answer a list of 11 question by a scale of 1 to 7. 1 means strongly disagree and 7 means strongly agree, and 4 means neutral. The study personnel were mainly interested to know if the device was comfortable or not, and if it was effective in engaging the subjects in doing more home daily activities. The recorded data were inspected for quality, and movement quality parameters (RaOM and IIM) were calculated in order to inspect if these parameters change in the second day after the study personnel has asked the participants to do extra exercising.

IV. RESULTS AND DISCUSSION

The following section presents the results of the user feedback questionnaire and the recorded data. Table I lists the questionnaire questions and the mean of responses on each question and the results of the t-test performed between the mean of responses of each question and a hypothesized mean of 4 [neutral score]. Results show a significant difference from the neutral score ($p<0.001$). In the open ended discussion, subjects expressed high satisfaction and reported that the visual feedback by the LEDs was engaging and motivating to move the impaired hand more than usual. They also expressed their willingness to use FMED at home for a therapeutic intervention because of being passionate to intensify their hand use during daily activities.

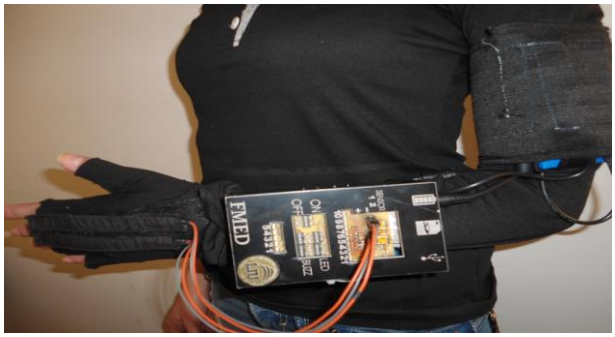

Figure 2: Prototype of FMED worn by a volunteer.

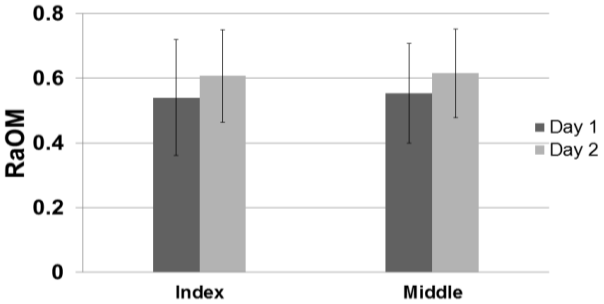

Figure 3:RaOM results for both fingers in days 1 and 2.

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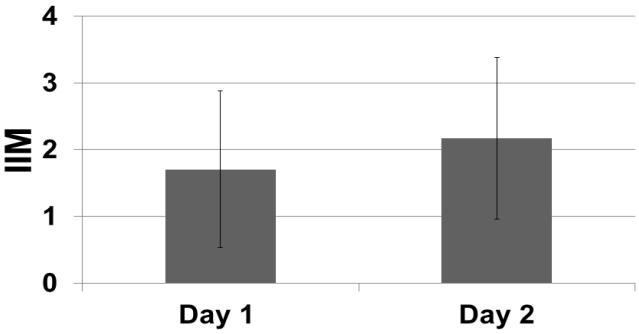

Figure 4: IIM results in days 1 and 2.

It should be noted here that the activity initially reported on day 1 might not faithfully reflect the regular activity of the participants without using the device; while wearing FMED subjects might be moving more than they usually do knowing that they are being watched. This is known as the Howethorne effect [18]. However, the participants are stroke survivors and they have movement impairments. Thus, the Howethorne effect will not increase the movement score beyond subject's true functional capability although it might increase the amount of his or her movement in comparison to regular days. This brings us back to another argument which says that it is helpful if these individuals with movement impairments felt they are watched so they move more according to their functional capability. In addition, being watched and by getting positive visual feedback of their movement (like the feedback by the LEDs in FMED), they will get better engaged in daily life functional activities, more than they averagely do. This is believed to be helpful in avoiding the learned non-use phenomena in stroke survivors where the less they use their impaired limb the harder it gets for them to recover their motor skills due to brain remodeling over time[9].

V. CONCLUSION AND FUTURE WORK

FMED allows clinicians to evaluate the improvement of hand function in the context of home environment. It can be a useful tool to complement the role of standardized outcome measures by assessing the hand use in real life so that clinicians are not limited to the clinical setting. The high rate of acceptance of FMED by the participants in this study and high enthusiasm of patients to using it for therapy, especially due to the presence of visual feedback suggests the need to test the usability of FMED in a home-based rehabilitation therapy intervention especially that it can be produced with a very low cost (~$100). Low cost, user friendly, and low weight, are the main advantages of FMED in comparison to other hand motion tracking gloves that are available in the market in addition to the presence of visual feedback setup which allows FMED to be useful as a therapeutic tool not just as movement recording device. In the future, additional testing will be done to evaluate FMED as a tool to evaluate the use of impaired hand during home-based therapy.

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Management System of Medical Equipment in Hospitals

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***Abstract*— In the hospital, the management of medical equipment is a series of activities from budget planning to equipment disposing. The overall activities focus on issues such as quality, safety, performance, cost, and profit. An efficient and effective management system is necessary for supervising these goals. The main problem faced in most of the Lebanese hospitals is the over load that is applied from both paper work and maintenance issues at the same time, resulting in department breakdown and/or limitations. In this paper, we show an equipment service life-cycle model applied in these activities for in-house clinical engineering department, beside an in-house cycle management, in addition to a tool of communication with the other departments in the hospital. Some information systems were built by the management system and the information of management operations in clinical engineering department can be systematically collected and revealed at different life-cycle stages by these systems. Through the management system, we can easily integrate the management activities and improve medical care quality and patient's safety.**

Keywords-Management system;communication;in-house cycle management.

I. INTRODUCTION

Nowadays, the healthcare sector is indispensible to us in order to maintaine a healthy life away from desease, but it is very expensive. Hospitals, private or public, tend to ensure the health service in every region on the Lebanese ground. Various departments are present in each hospital that work together to guarantee the safety of the patient beside the appropriate medication and therapy. Depending on the patient's case, he/she will be transferred to one of the departments and will remain there as long as necessaryto complete treatment. Departments within the hospital are divided into therapeutic, diagnostic, and service departments [1]. Every part in the hospital is related to another, thus linked together to form a strong chain to make sure that the patient is better in his stay and nothing is missed in his therapeutic period. Our concern is in the service sector, and especially in the Biomedical Department which is responsible for all the pieces of equipment in the hospital, their history, specifications, failure, and cost. This is very important in order to insure quality health survice to the incoming patients.

Working as a biomedical engineer in a hospital requires being able to handle multiple tasks in parallel, such as technical issues and following up with different companies, as well as managing paperwork. Problems are found in the management part which is the result of hundreds or thousands of papers on the engineer's desk each month. Papers consist of maintenance requests, transfer forms, preventive maintenance requests, discard forms, etc.

The work mentioned increases the load on the biomedical engineer who is probably the only one in the department doing everything as a one man show. Paper work take a lot of time and disperses the process of parallelism mentioned previously [2]. On the other hand, each three years, the biomedical engineering department should be prepared with all these necessary data following the Accreditation standards to be submitted to the Ministry of Health. For that, all the requirements mentioned before should be available and well organized at any time.

And here is the importance of having a management system that can control the cycle of this work between the departments and the biomedical department, and a tool that can be used to apply this management system [3].

The main goal of the proposed project is to develop a management system that can organize the work pathway between the main department which is the Biomedical, and the secondary parts which are the hospital departments (Emergency, Operating Room, Intensive Care, etc.). What we mean by a management system is actually a process that is controlled by the biomedical engineer to stay in contact and updated with the secondary departments, which provides an improved quality of healthcare delivered to the patients. The system is ridden by a tool which is a software divided into a server user and active users. The main server/program is the biomedical engineer in the hospital. Active users represent the departments found in the hospital. Users can send maintenance requests, write transfer forms, and apply a request for preventive maintenance or exams for the staff. Each department, when using the program, is restricted to the machines found in this department [4]. On the other hand, the server can manage everything in all the departments due to a database that consist of the history of biomedical equipment. The server can also send recommendations and actions to the requests sent. In addition, the engineer can enter all the data that belongs to each machine which result in a history record of each

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equipment from the moment bought reaching the discard phase. Policies, procedures, and instructions of use are also available in the software. Several processes (depreciation value, repeated failure, etc.) will be implemented in the program to help the engineer in some decisions he might take.

Using this tool, the management system can be applied easily upon controlling and gathering all the required data beside tracking equipment, counting repeated failures and taking critical decisions concerning hospital improvement which is directly related to the patient's safety and the quality of the delivered healthcare services.

The following section (section II) will shed lights on structure of the Lebanese hospitals with the biomedical engineering's tasks. Section III will cover the system design and implementation. Results and discussion are stated in section IV. Finally, the conclusion is set in section V.

II. HOSPITALS IN LEBANON

Hospitals in Lebanon are mainly divided into public and private. Each hospital has its own divisions. Departments within the hospital follow one of the three classes: Therapeutic, diagnostic, or service. The Biomedical department is one of the service departments that are not only connected to all the other hospital departments, but also to external parties such as companies and agencies.

The biomedical engineering departments should deliver continuous learning about the proper use of medical equipment to the doctors and nurses; communicate with the vendors, hospital administration, third party payers, and leasing agencies to take the right decision about the cost, technical requirements, reliability, and future planning. On the other hand, biomedical engineering department should communicate with the hospital environment section to take care of waste management, power, cabling, maintenance, and safety.

Also, the department should insure the safety and accepted medical practices to overcome the regulation agencies. All of these connections are part of the daily tasks of the biomedical department to ensure the quality of healthcare delivered to the patient.

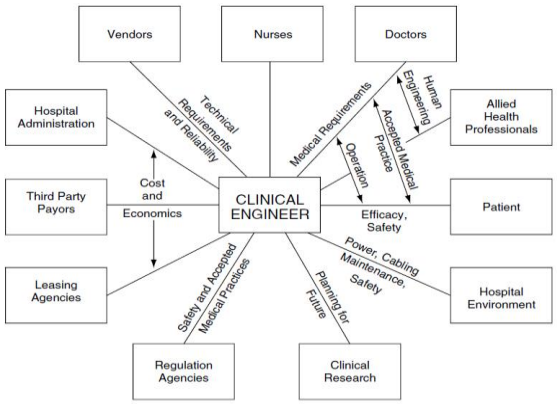

Figure 1.Connections of the biomedical department with inner and outer hospital environment [5].

The connections shown in figure 1 are essential to provide the best hospital environment with good equipment management, active department's communication, following defined procedures of purchasing and maintenance, etc., which all result in maximizing healthcare quality and ensuring patient's satisfaction.

All the mentioned tasks beside the paper work form a huge responsibility on the biomedical engineer in the hospital.

Since all these tasks, beside the paper work, are related, it becomes essential to have a computer based management system to facilitate the inter-communication between the biomedical engineering department and all the other departments to save the time consumed on paper work and helps in decision making.

III. SYSTEM DESIGN AND IMPLEMENTATION

A Hospital Management System is a way for making the management inside the hospital paperless. This includes the clinical, back office, and generic management of all activities. It integrates the entire resources of a hospital into one integrated software application. The most important benefits that the biomedical engineering department gains from this management system are: minimizing manpower requirements, instant information retrieval, and timely treatment decisions.

It's a well know fact that there is no common hospital management system applied worldwide [6]. Each country has a certain system applied in some of its hospitals based on the country's conditions and standards from one side, and the hospital's profession, level, and type from the other side.

An existing management system in Michigan is based on dividing the biomedical department and the hospital equipment into several subdivisions [7]. Also, the management system applied in New Delhi defines the maintenance categories, as well as defining the function and the troubleshooting process of various medical equipment [8]. In Kenyan hospitals, a software is developed and installed in each department to identify the equipment fault and reports the possible personnel to handle it [9].

Our management system for the Lebanese hospitals should consist of:

A. Number of Staff:

The number of staff varies according to the number of beds in the hospital as shown in table I.

According to the number of beds within the hospital, the number of staff can be easily calculated such that every 100 beds need one biomedical engineer and one biomedical technician [7] [8].

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TABLE I. Number of biomedical engineering staff with the corresponding number of beds.

	0-50 Beds	50-100 Beds	100-150 Beds	150-200 Beds
Biomedical Engineer	1	1	1	2
Biomedical Technician	0	1	2	2

B. Roles and Responsibilities:

- **Biomedical Technician:** Different tasks are assigned to the biomedical technician in the biomedical engineering department. He is the biomedical engineer's assistant, responsible for daily checkup mainly for the life support equipment such as defibrillators, anesthesia machines, etc., to make sure that everything is normal and ready for functioning. Checking the medical gases, such as oxygen, nitrogen, and compressed air to ensure the volume and pressure of each is also one of the biomedical technician's tasks. On the other hand, the technician should follow up the temperature in some of the departments like Cath Lab, CT scan, MRI, etc… and the level of Reverse Osmosis (RO) water and the corresponding Total Dissolved Substances (TDS) and make sure the normal functioning of the autoclaves as well.
- **Biomedical Engineer:** The Biomedical engineer should set the maintenance schedule that is composed of two parts: Planed Preventive Maintenance (PPM), and Corrective Maintenance (CM), to guarantee the efficiency and accuracy beside the normal function of medical equipment in the hospital. Moreover, the engineer is responsible for the stocks that contains the spare parts and stand by items and check for the missing/needed ones to order them. Designing new department, equipment installation, meeting with companies, and new equipment planning are also tasks assigned for the biomedical engineer in the hospital.
- **Software:** The software is the tool for applying the hospital management system. It is developed using vb.net language. The software is based on Administrator-Client Inter-phase [9]. The administrator is the biomedical engineering department, whereas the client may be any other department within the hospital. In figure 2, the front page of the administrator's software is shown.

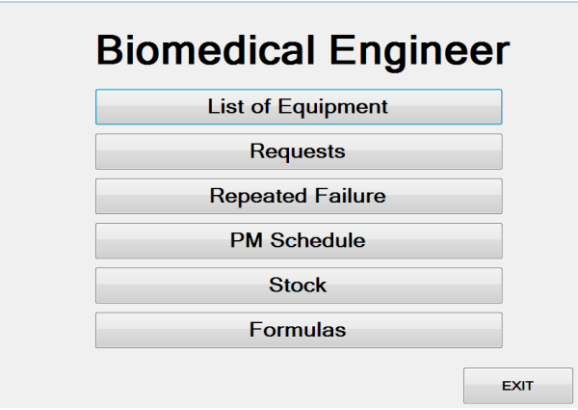

Figure 2.The front page of the administrator's (Biomedical Department) software.

The biomedical department represents the head of the management system software. The other departments are the clients in this software. The software consists of:

- **List of Equipment:** It lists the medical equipment found in each department with the corresponding details about the location room, serial number, hospital code, model, brand, purchasing date, price, and the availability of the operating manual. Also, a list of the discarded equipment/accessory in each department is available. Figure 3 illustrates the list of equipment found in the ground floor of the hospital with all the corresponding details that can be seen by both the engineering and the relative department.

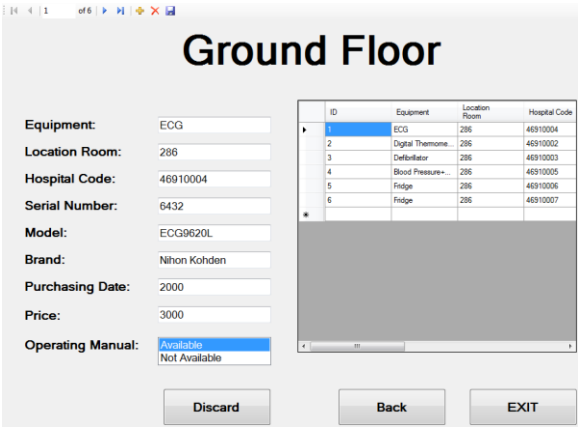

Figure 3.The ground floor's list of equipment software layout.

- **Requests:** Requests are divided into maintenance requests and transfer requests. The administrator (Biomedical Department) receives requests sent from any other department. The maintenance request contains all the information about the equipment in addition to the failure date, time, type, description, expected maintenance duration, current status, finish date, and accessories needed.
  The transfer request consists of all the information about the equipment in addition to time, date, and duration of transfer, and the targeted location beside the reason of transfer.
- **PM Schedule:** Figure 4 shows the PM schedule set by the biomedical engineering department. PM schedule is divided into internal (In-house), and external (company) preventive maintenance. The

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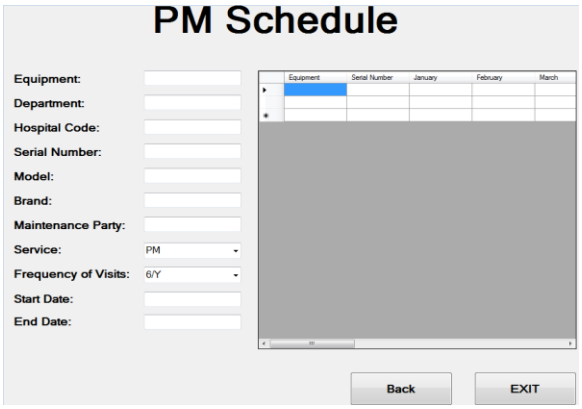

Figure 4.PM schedule layout in the administrator's software page.

schedule also shows the equipment and their corresponding dates of PM in addition to the maintenance party.

- **Stock:** Includes the spare parts/items found in the department and their quantity as shown in figure 5.

- **Repeated Failure:** This part allows the biomedical engineer to search by serial number or date interval to list the number of failures of equipment beside all the needed information. The repeated failure is a clear indicator that gives the biomedical engineer strong evidence and clear statistics about the equipment history, thus helping in taking the appropriate action and highlighting the equipment that should be replaced to guarantee the safety of the patients, as well as increasing the number of patients benefiting from the delivered healthcare.

- **Formulas:** The biomedical engineer can implement any formula that helps him in taking decisions in a more reliable and fast way. Figure 6 shows one of the useful formulas which is the depreciation value [10].

- **Instructions of use:** The page allows the staff in the department to view the instructions of use of all the equipment found in their department. Instructions of use contain details about getting started with the equipment, safely use, cleaning procedure, etc., these details should be clear to all the staff in the department to ensure the best use of the equipment with best results regarding the patient's diagnosis/treatment.

- **Security:** For the administrator software version, a username and password are used to guarantee the data security and private access. On the other hand, the client software version is more flexible to let all the staff access the information needed and send the requests directly; but any modification requires a username and password.

The biomedical engineer can enter, edit, and delete data about medical equipment in the hospital. He has a full access to the software. However, the clients can only view the instructions of use, send maintenance/transfer requests, and receive feedback from the biomedical department concerning the request sent. The biomedical department receives a notification upon any new request. In return, the client also receives a notification upon any feedback received.

The network security of the software is a part of the overall hospital network security.

IV. RESULTS AND DISCUSSION

The management system and the software were implemented to test the functionality and activity of the overall system. The administrator version was installed on the main computer of the biomedical department. The client version was installed on the computers of all the medical departments. The software's communication is done by using the internal network of the hospital with the help of the information-technology department.

Upon failures in any medical equipment, the department sent a maintenance request. When receiving the notification of a new request, the biomedical engineer checks the software to verify the location of the failed equipment beside a brief description of the failure found, thus, takes the needed action. The engineer in return sends a feedback about the duration of maintenance and fills the missing information in the software to fulfill the data entry step.

The biomedical engineer in his department, and using the software, was able to send/receive data and communicate with the other departments within the hospital. He also checks the PM schedule, as well as following the biomedical stock of spare parts. On the other hand, the department was able to view, add, remove, and edit any

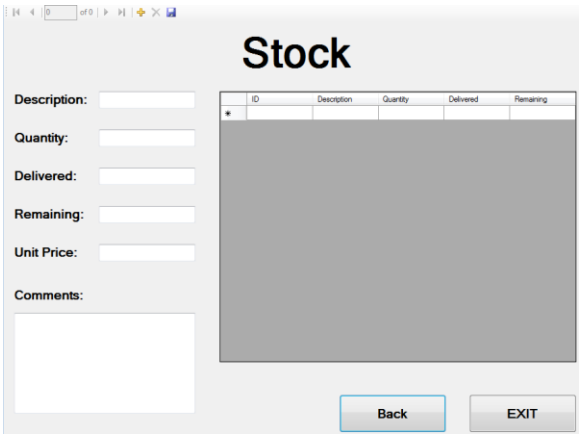

Figure 5. Stock's page with the corresponding details.

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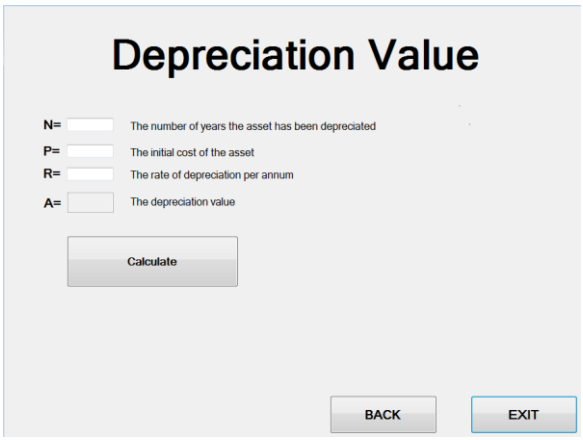

Figure 6.Depreciation value is one of the implemented formulas in the software.

equipment with its details using the list of equipment part in the software.

Things were better using the software. Time was saved in a great way with less paper work and reduction of over tasks that were due the responsibilities of the biomedical department.

The most important thing was that everything was ready for the accreditation that is done by the Lebanese Ministry of Health approximately each three years.

As a result, the management system and the software achieved the mentioned tasks and diminish the problem stated at the beginning of this paper in a computerized way based on databases and inter-communication between the biomedical and other hospital departments.

V. CONCLUSION

The implementation of this management system in the Lebanese hospitals can ensure the proper functioning of the biomedical department in the hospital since it saves time, archive data, helps in decision making, and make reviewing the medical equipment history easy. Besides, the system activates the inter-communication between the biomedical department and the other departments, sets the work pathway, and organizes all the data that the biomedical engineer needs.

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Automatic Measurement of Pronation/Supination, Flexion/Extension and Abduction/Adduction Motion of Human Limbs using Wearable Inertial and Magnetic Sensors

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***Abstract*—This research deals with the design and programming of devices for measuring automatically human motion using portable and low-cost technologies. The movements studied in this research are pronation/supination, flexion/extension and abduction/adduction of the upper and lower limb, which are required for a number of activities of daily living. A home-made attitude and heading reference system based on inertial and magnetic sensor is presented. It was compared with a similar device available in the market, and with respect to a video-camera based system used as gold standard. An experimental platform was also built for controlling and replicating experiments. The results obtained by the proposed device are competitive and promising with a general performance comparable to a commercial device.**

***K**eywords- ubiquitous healthcare; real-time medical data collection; systems for measuring tissue parameters.*

I. INTRODUCTION

This research focuses on designing automatic methods and technologies for long-term and continuous monitoring of human motion related to functional activities of daily living, namely pronation/supination flexion/extension and abduction/adduction of upper and lower limbs.

The pronation/supination describes the motion of a radioulnar articulation such as the wrist and comprise the pronation or internal rotation, and the supination or external rotation, palm-down and palm-up for the wrist, respectively. The flexion/extension describes the motion around a hinge joint such as the elbow and comprise the flexion, a bending movement that reduces the angle between the segments linked by the joint, and the extension or straightening movement that increases the angle between the linked segments. The abduction/adduction describes the motion away and towards a midline, such as the axis of the body, it comprises the abduction or movement of arms or legs, for instance, out to the side, and the adduction or movement to bring the limbs back in.

The movements of pronation/supination and flexion/extension are required for a number of activities of daily living such as feeding, handwriting, typing, picking up and holding objects, just to mention examples involving the upper limb [1], whereas abduction/adduction of the lower limb plays an important role in activities such as walking and running. In general, these movements are important when assessing functional abilities, determining therapeutic intervention or athletic programs for enhancing skills, and are also relevant signs for neuromotor development and neuromotor function associated with aging [2].

The measurement of pronation/supination, flexion/extension and abduction/adduction for assessing functional abilities relies commonly on both, goniometric measurements and the observation of physicians and trained therapists, that do not ensure a uniform assessment.

Nowadays, portable inertial and magnetic sensors as well as powerful, inexpensive and tiny micro-processors enable the development of wearable technologies for measuring movement related to functional abilities on a long-term and continuous basis. Also, these conditions offer a unique opportunity to reach broad segments of the population. These devices are known as Attitude and Heading Reference Systems (AHRS).

It is worth to mention that commercial AHRS present two main drawbacks. First, they are developed as black boxes, offering limited possibilities for extending or adapting them to user's needs. And second, commercial AHRS are usually general-purpose devices that are not specifically intended for measuring human motion. Therefore, we strongly believe that developing a home-made AHRS is a way to overcome these limitations.

This article describes the design of a home-made AHRS (HM-AHRS) using inertial and magnetic sensors. The HM-AHRS is programmed to automatically estimate its orientation from which a joint angle is deduced. It was evaluated using a set of tests of pronation/supination, flexion/extension and abduction/adduction movements. A specific platform for conducting these tests was built. Eight people participated in the tests; they worn both our HM-AHRS and a commercial AHRS, a LPMS-B device (LP-research, Japan). Simultaneously, movements of individuals were tracked by a video-camera based system. Our HM-AHRS obtained competitive results.

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The main contribution of this research is the implementation of an AHRS device from the scratch with a performance comparable to a commercial AHRS in the measurement of human motion, namely pronation/supination, flexion/extension and abduction/adduction of upper and lower limbs. This is a challenging problem and it also poses issues such as the lack of external references, the deformation and stress of soft tissue, and the noise and drift that usually affect inertial sensors.

The rest of this paper is organized as follows: Section II revises the most significant related work. Section III describes the design, implementation and programming of our HM-AHRS. Section IV presents and discusses the results that were obtained. Finally, Section V gives concluding remarks and some perspectives of this research.

II. Related work

In this section we briefly revise significant related work.

Lee et al. [3] designed an array of accelerometer-based nodes to measure flexion/extension of upper limb. Their device is tested first on a programmable rotary stage and then compared to an electro-mechanical goniometer in experiments involving one individual. The power consumption of the nodes and communication issues are also investigated in this research. Namely, the latency of a system comprising various nodes for measuring simultaneously multiple joints is calculated with interesting results.

El-Gohary and McNames [4] combined two inertial measurement units containing each one a triaxial accelerometer and a triaxial gyroscope, and kinematic models to control robotic manipulators to estimate human joint angles. The proposed method was tested for pronation/supination movement of the forearm, abduction/adduction movement of the shoulder, and flexion/extension of the elbow, using eight subjects performing normal and fast movement. Also, it was evaluated against an optical reference system with good results. A similar solution was studied by Zhou et al. [5].

Zhang et al. [6] focused on the problems of inertial drift and acceleration interference that affect inertial and magnetic sensors. They proposed schemes for filtering and data fusion, and conducted tests for tracking motion of upper limb using an array of three units of triaxial inertial and magnetic sensors. The outcome of the proposed method in represented as quaternions, that are directly compared to the outcome of a reference system, a BTS SMART-D optical motion tracker (BTS BioEngineering, Italy) involving one individual.

Kaneko et al. [2] developed a portable evaluation system for pronation/supination movement of the forearm using four wireless inertial sensors. From the obtained measurements reference curves for both, neuromotor development for children and changes in neuromotor function for adults are obtained. Even though the cited system has been extensively tested, with several hundreds of subjects, any alternative device or system is considered to compare its performance.

Bonroy et al. [7] developed a brace to measure flexion/extension movement of the knee using two accelerometers and one inductive sensor for static and dynamic measurement, respectively. These measurements are used to classify physical activities of ten healthy subjects, such as walking, ascending and descending of stairs, and fast locomotion. Previously, the system was compared against a Vicon optical motion capture system (Vicon Motion Systems, UK) with competitive results. However, the authors focused on classifying activities based on pattern detection in form of peaks.

Lambrecht and Kirsch [8] implemented an AHRS module using inertial and magnetic sensors. Two variations of AHRS were tested, one relying only on inertial sensors and one relying on both inertial and magnetic sensors, and compared against an active-marker motion capture system, Optotrak Certus (NDI, Canada). The range of movements tested in this research is wide and comprises seven degrees of freedom of upper limb, *i.e.*, azimuth, elevation and internal rotation of shoulder; elbow flexion; forearm pronation; and flexion and deviation of wrist. The results that were obtained are very good, however tests were conducted using only one individual.

In contrast to previous work, four important features of our system can be highlighted: (1) it relies only on one inertial and magnetic measurement unit; (2) the same method is used to measure pronation/supination, flexion/extension and abduction/adduction of upper and lower limbs; (3) its performance is compared with an analog device and with respect to a gold standard based on a video-camera tracking system; and (4) it was tested with a group of people, in this case eight individuals.

III. Measurement of Pronation/Supination, Flexion/Extension and Abduction/Adduction

This section is divided into two parts. The first one provides technical details of the instruments used in this research and describes also the experimental settings. The second one summarizes the methods and algorithms that were programed in our HM-AHRS.

A. Setup

This part describes the physical components and conditions of the experiments conducted for our research.

1) Measurement Instruments: Two different devices AHRS were used, our HM-AHRS and a LMPS-B. A video-camera based system to calculate ground truth values was also used. Both AHRS devices as well as the video-camera based system operate with a sampling rate of 50 Hz. In all the experiments described in this research both devices AHRS were worn simultaneously by the subjects, and meanwhile the experiments were recorded by the video-camera based system. More specifications of these instruments are detailed below.

- HM-AHRS. The Home-Made Attitude and Heading Reference System comprises an ArduIMU v3 (3D Robotics, USA) with three different MEMS sensors (3-axis gyroscope, 3-axis accelerometer and 3-axis magnetometer), on-board Atmega328 microprocessor running at 16MHz, bluetooth RN-42 communication module for distances up to 20m, and a lithium battery of 3.7V at 1000mAh. The approximate weight of HM-AHRS is 35g.
- LPMS-B. The LP-Research Motion Sensor Bluetooth version is a miniature wireless inertial measurement unit (IMU) / attitude and heading reference system (AHRS). This device includes three different MEMS

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sensors: 3-axis gyroscope, 3-axis accelerometer and 3-axis magnetometer. Its communication distance scope is 18m, it has a lithium battery of 3.7V at 800mAh, and it weights 34g.

- Video-camera based system. The video system consists of both, video-camera and tracker software. The video-camera is a Nikon D5200 with 24.1MP CMOS sensor and Full HD (1900×1080p) video recording. The tracker software is a free video analysis and modeling tool built on the Open Source Physics (OSP) Java framework, able to track a visual mark and calculate its orientation with respect to a given axis.

2) Experimental settings: To perform pronation/supination, flexion/extension and abduction/adduction tests, an experimental platform was designed and built. It consists of a translucent rectangular frame of 80×80cm and a weight of 3kg, with a rotatory circular plate in the middle with visual marks and limit stops (see Figure 1(a)). These stops can be manually adjusted and set on arcs of 30 and 60 degrees. Additionally, the rotatory plate has three handles for short frontal (pronation/supination test of forearm), short lateral (flexion/extension test of forearm and shank) and large lateral (flexion/extension and abduction/adduction tests of arm and thigh) movements, as illustrated in Figures 1(b), 1(c), 1(d).

A sketch of the general setup involving the measurement instruments and the experimental platform used in our research is given in Figure 2. It is important to notice that all estimations are made locally by AHRS devices, and the server is only in charge of data acquisition for further comparison.

B. Methods

1) Subjects and conditions: Eight asymptomatic subjects participated in the tests, 6 men and 2 women, with a mean age of 27.3 (±5.07) years, and a height of 1.69 (±0.08) m. All subjects gave their informed consent to participate in these experiments.

Both AHRS devices were placed on the forearms of test subjects using an adjustable elastic band with axes manually aligned previously using a mechanical goniometer. To neutralize the movement of the shoulder a belt attached to the body at the level of the breast was used.

Since both devices are wireless there is no need of additional cables that might obstruct the movement of the limbs.

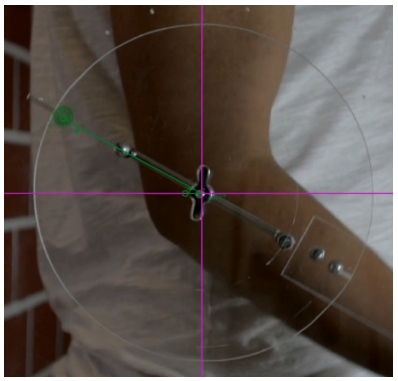
Each subject performed two sets of movements for these: pronation/supination of the forearm; flexion/extension of forearm and arm; flexion/extension of thigh and shank; abduction/adduction of the arm and thigh.

For the first set of movements involving upper limb, subjects were asked to repeat systematic movements within an arc of 60 degrees at normal speed, and for those involving lower limb, subjects were asked to repeat systematic movements within an arc of 30 degrees at normal speed. For the second set of all sort of movements, subjects were asked to perform freely movements at their own pace. These movements were performed by the subjects in random order.

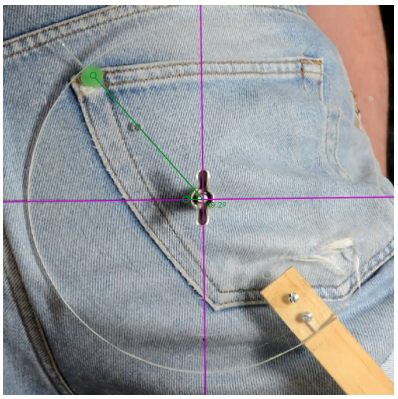
Since all the instruments utilized to measure angles operate independently, a post-processing for synchronizing datasets was applied. A controlled start time for each instrument was

(a) Experimental platform

(b) Pronation/Supination test



(c) Flexion/Extension test



(d) Abduction/Adduction test

Figure 1. Details of the experimental platform and measured movements.

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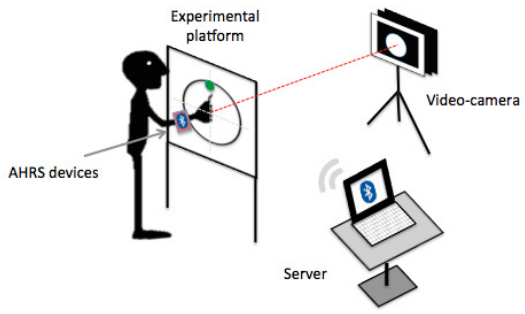

Figure 2. Setup of experiments.

established, for aligning independent signals in function of time; the start time was also used to adjust the initial magnitude of the instruments, 90 degrees for pronation/supination and 0 degrees for flexion/extension and abduction/adduction tests.

2) Algorithm: Inertial and magnetic sensors comprised in AHSR devices calculate linear acceleration, angular velocity and magnetic fields. Even though calculating angles from these values is possible, by applying for instance a straightforward integration of multiple readings of linear acceleration, the resulting value is subject to inaccuracy, specially over long periods of time. In effect, these sensors produce highly variable signals and they are susceptible to noise, for instance accelerometers and gyroscopes are affected by drift whereas magnetometers are affected by magnetized objects.

To the previously mentioned technical limitations of the sensors of AHRS devices, two issues that increase the complexity of the problem of measuring pronation/supination, flexion/extension and abduction/adduction motion must be also considered. The first one is tracking moving objects without any external reference to which the system can be tied. And the second is measuring motion of objects affected by deformation and stress of soft tissue.

For these reasons, algorithms for AHRS devices typically combine evidences provided by both, inertial and magnetic sensors, to improve the accuracy of estimations, and apply self-calibration and filters to reduce or compensate noise. This is also the way in which our AHRS has been programmed, which is based on complementary filtering.

Our algorithm is divided into three main stages: (1) calibration, (2) estimation, and (3) correction. The algorithm is sketched in Figure 3 and the main stages are described below.

- **Calibration**. For calibrating inertial sensors they must be exposed to various situations and then measure the actual error.
  In our case, the calibration of the accelerometer is done in this way, the sensor is moved gently in all possible orientations. For each axis, the maximum and minimum values from the obtained readings are identified, a range and the mean of the range are determined from these thresholds. Next, the error or offset is calculated by subtracting the mean to the known value of gravity, that is 1g. Once calculated the offset it will be subtracted from the raw readings from the accelerometer.
  For the calibration of the gyroscope an average of readings while the sensor is static is first calculated, the offset. Then, the offset is subtracted from the raw readings from the gyroscope.
  The calibration of the magnetometer to reduce the distortion of the magnetic field is a bit more intricate than previous ones. It comprises one similar step where the sensor is turned in all possible orientations and then an average error or offset is calculated for each axis. The second step requires the calculation of a rotating matrix to multiply the actual readings of the sensor, distributed in the shape of an ellipsis, and transforming the distribution into a sphere. These steps are known as correction of hard and soft iron errors, respectively.
  The stage of calibration is made once (step 1 of the algorithm) and must be recalculated each time the experimental conditions have changed.
- **Estimation**. In this stage, a first calculation of angles is performed. Since this calculation is inaccurate and is revised in a next stage, these values are considered as "estimations".
  In our case, the initial readings from sensors are obtained (step 2). From the readings from the accelerometer and magnetometer, a rotation matrix known as the Direction Cosine Matrix (DCM) is calculated (step 3). Then the rotation matrix is updated using the readings from the gyroscope (step 4). The readings from the gyroscope are integrated taking into account a measurement error (Me). Initially Me is equal to 0 and is updated in a subsequent stage. Finally, the rotation matrix is normalized to preserve its orthogonality (step 5).
- **Correction**. In this stage, estimations are corrected by applying known error models of the sensors.
  In our case, the drift error is corrected by using the readings from both, accelerometer and magnetometer, taking into account known errors of these sensors (step 6). In our algorithm, this value was obtained from the data sheet of the sensors. With these values, the measurement error Me is updated (step 7). Then Euler angles are calculated from the rotation matrix (steps 8 and 9).

The stages of estimation and correction are alternated from now on from step 2. The measurement error calculated in step 7 becomes the known error in the next iteration.

IV. Results and Discussion

One hundred and twelve sets were processed in total (16 for the experiments of pronation/supination, 64 for flexion/extension, and 32 for abduction/adduction), all comprising the angles calculated by three sources: (1) the commercial AHRS, a LPMS-B device, (2) our HM-AHRS, and (3) the video-camera based system or gold standard.

The root-mean-square error (RMSE) between the estimated values of AHRS devices and the ground-truth values, as well as the Pearson product-moment correlation coefficient (PCC) for the same values were calculated. Tables I, II and III summarize the results per treatment (arcs of 60 degrees for upper limb and 30 degrees for lower limb, and also free movements for both limbs).

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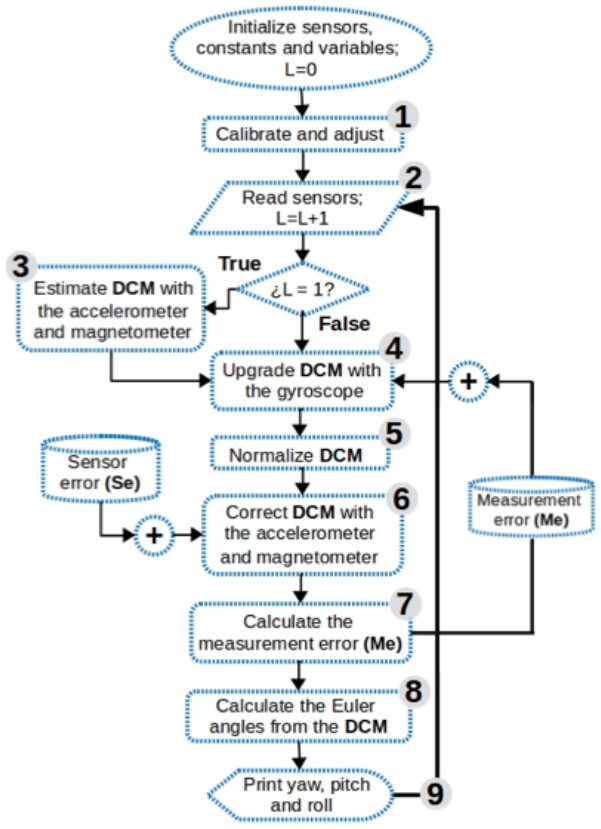

Figure 3. Algorithm used to calculate AHRS orientation, and then angles of pronation/supination, flexion/extension and abduction/adduction movements. L is an index of iterations.

TABLE I. RESULTS OF PRONATION/SUPINATION EXPERIMENT. IN THE COLUMN $Treatment$, f STANDS FOR FOREARM.

	LPMS-B		HM-AHRS	
Treatment	°RMSE mean (SD)	PCC	°RMSE mean (SD)	PCC
f/60°	4.81 (0.98)	0.98	4.62 (1.03)	0.99
f/Free	9.78 (2.42)	0.99	9.11 (1.78)	0.98

TABLE II. RESULTS OF FLEXION/EXTENSION EXPERIMENT. IN COLUMN $Treatment$, f STANDS FOR FOREARM, a FOR ARM, t FOR THIGH AND s FOR SHANK.

	LPMS-B		HM-AHRS	
Treatment	°RMSE mean (SD)	PCC	°RMSE mean (SD)	PCC
f/60°	2.35 (0.59)	1.00	2.90 (0.59)	1.00
f/Free	3.63 (0.85)	1.00	4.76 (2.04)	1.00
a/60°	2.51 (0.61)	0.99	2.32 (0.66)	1.00
a/Free	3.63 (1.04)	0.99	3.26 (0.97)	1.00
t/30°	2.30 (0.73)	0.99	2.56 (0.71)	0.98
t/Free	2.79 (0.81)	0.99	2.91 (0.80)	0.99
s/30°	1.57 (0.50)	0.99	1.63 (0.45)	0.99
s/Free	2.60 (0.47)	0.99	2.98 (1.04)	0.99

TABLE III. RESULTS OF ABDUCTION/ADDUCTION EXPERIMENT. IN THE COLUMN $Treatment$, a STANDS FOR ARM AND t FOR THIGH.

	LPMS-B		HM-AHRS	
Treatment	°RMSE mean (SD)	PCC	°RMSE mean (SD)	PCC
a/30°	2.17 (0.49)	1.00	2.37 (0.94)	1.00
a/Free	3.30 (0.99)	1.00	2.69 (0.97)	1.00
t/30°	1.79 (0.43)	0.99	2.14 (0.61)	0.99
t/Free	1.96 (0.51)	0.99	2.19 (0.69)	0.99

Two remarks can be highlighted from these tables. First, there is a very good agreement between the estimations made separately by independent devices with respect to the ground-truth values, as can be seen in the high correlation between the compared values (columns PCC). Second, the performance of both AHRS devices is quite similar, according to the mean error calculated for treatment (columns °RMSE).

On average, the LPMS-B device is up to 0.35 angle more accurate than the HM-AHRS device for small arcs (30^o) for all treatments, whereas for larger arcs (60^o and free movements) the scores of both devices are close. There is a difference of up to 0.55 and 1.13 degrees for movement within arcs of 60^o and free movement, respectively.

These results were obtained from experiments that lasted short periods of time, as usually required for assessing functional activities in laboratories. Longer tracking periods are more prone to errors and noise, and more sensitive self-calibration methods and filters must be designed for correcting these drawbacks and enabling AHRS devices for daily uses.

However, it is worth to remark that our HM-AHRS achieved a performance comparable with a commercial AHRS, according to a video-camera based system using a standard software for optical tracking.

V. CONCLUSION AND PERSPECTIVES

The design of an HM-AHRS device for measuring human motion is presented. Designing and programming our own tool is a decision made by our group to address the complex problem of measuring angles of human motion.

The HM-AHRS device relies on inertial and magnetic sensors, and a simple complementary filter running on a microprocessor embedded in the device. The HM-AHRS was tested with a group of real people for measuring pronation/supination, flexion/extension and abduction/adduction movements of the upper and lower limbs. It was compared to a commercial AHRS device from LP-research, and with respect to ground-truth values provided by a video-camera based system. An experimental platform was also designed and built for controlling and replicating experiments.

The results obtained by our device are very competitive, with a general performance comparable to a black box based on a commercial device.

The device described in this article is part of an ongoing research whose goal is to design reliable and low-cost devices for enhancing human-computer interaction for applications such as serious games, exergames, and interfaces for rehabilitation systems. In all these examples, the proper measurement of pronation/supination, flexion/extension and abduction/adduction movement of upper and lower limbs is considered crucial for designing reliable technologies.

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In the near future, we will work on the improvement of filters to better track human motion over longer periods. For that, more complicated filters such as Kalman filter is considered.

We will extend our work to combine the estimations made by pairs of our HM-AHRS device in order to calculate joint angles in which both anatomical references are dynamic, *i.e.*, for knee angle two AHRS devices are placed on thigh and shank, and angles are measured while both segments are in movement. These studies involve significant computational challenges, such as writing simple algorithms for local computation, establishing real-time communication among various AHRS devices, improving calibration, and incorporating sensors and methods for self-detecting a proper alignment of various devices, among others.

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Personalize Systems for Psychological Evaluation Performance and Vigilance Monitoring

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***Abstract* - This work deals with the monitoring of sleep deprivation, sleep disorders and investigative methods for their diagnosis. The aim of this work was to develop an algorithm for measuring and evaluating mental performance and vigilance tested. Computer based program consists of six tasks that tested memory, reaction time, coordination of movement and level of sleepiness using the Epworth Sleepiness Scale. Sixty measurements were performed using the above mentioned program. These data were statistically processed and characteristic values were determined for a select group of healthy people. For the creation of the program, the Visual C# development environment was used, and the measured data are stored in a MS Access database on cloud. Statistical data processing was done in software Statgraphics Plus.**

Keywords - sleep disorders diagnosis; Epworth scale; mental performance; vigilance; statistical evaluation.

I. INTRODUCTION

Sleep is a basic biological need. It is characterized by reduced movement activity and reduced reactivity to external influences. The body while it rests, function system slows down and starts running the regenerative processes. The changes in physiological changes, reduced body temperature, slowing of the heart and respiratory rate, reduced blood pressure, changing hormone levels in the brain. Good quality sleep is important for maintaining good physical and mental health. It is essential for the proper functioning of the central nervous system (CNS), assists in tissue regeneration and healing, promotes healthy growth, and restores the immune system and thereby increasing the body's resistance to disease.

Total sleep time per day for different animals differs greatly, approximately from 2 hours to 20 hours. The sleep duration for humans is individual. It is reported that the average sleep of humans lasts 7-8 hours, but some individuals have different sleep needs can vary from 4 to 12 hours of sleep per day. [1],[2]

A. Sleep Disorders

Studies show that 40% of adults have sleep problems and their number increases with increasing age. About 25% of adults indicates occasional sleep disorders, 10% are difficulties permanent and 5% of respondents suffer from excessive daytime sleepiness, and it influence work is social impact on their quality of lives. Under the current international qualification with sleep disorders divided into six basic categories: insomnia, respiratory disorders linked to sleep, hypersomnia, circadian rhythm disorders, parasomnias and abnormal movements linked to sleep.

B. Circadian Rhythm Disorders

Circadian rhythm disorders arise different timing of our own biological rhythm or the rhythm desynchronisation required external environment. Among these syndrome disorders include changes time zones (jet lag syndrome), which arises time shift during transcontinental flights. Other disorders related to circadian rhythm shift work. Daytime sleep for workers who perform night shift, fully substitute its length or quality night's sleep. In delayed sleep phase one goes to bed around 2 to 4 hours of the morning and getting up late in the morning until noon. Conversely, at advanced stages people go to bed early tonight (18 to 20 hours) and wakes up very early in the morning (1 to 3 hours).[3, 4]

C. Symptoms of Sleep Deprivation

Symptoms include emotional problems, anxiety, stress and depression, people are irritation. During prolonged insomnia may occur disorientation and problems with speech. These symptoms usually disappears after sufficient sleep and have no other consequences. Chronic insomnia can have long-term consequences, such as high blood pressure, heart failure, and psychiatric problems in the worst case, death.

D. Exploatation

Sleep deprivation is used in scientific studies to investigate the function sleep and its biological mechanisms. Most often used in laboratory rats, for which examines how total sleep deprivation and deprivation of REM or NREM only phase. Lack of sleep is also used as a torture and interrogation techniques. This fact is used tired that people are more likely to speak the truth. Investigation is the first kept awake for several days and then when he is finally allowed to fall asleep, suddenly awakened and interrogated. According to recent studies it is possible to use sleep deprivation, also for the treatment of depression. This stages have to be measured and analyzed especially for industry and medical application and safety maintenance. [5],[6],[7]

E. Examination Methods

The basic step for the diagnosis of sleep disorders is a detailed medical history specifying sleep and diet excluding exogenous factors (drugs, alcohol, drugs).This history some patients sufficient for a diagnosis. Character disorder specify sleep questionnaires, eg. sleep diary, Epworth sleepiness scale or Stafford sleepiness scale (ESS). Basic testing method is polysomnography. The differential diagnosis individual failures is used multiple sleep latency (MSLT) and maintain wakefulness test (MWT) which is determined using the measure of daytime

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sleepiness. The independent self-monitoring system for sleep deprivation and vigilance is not common or the systems are under psychologists and neurologist's control in ambulance. [8],[9],[10],[11]

II. Measurement of Mental Performance and Vigilance

The aim of this work was to design and develop a methodology for testing and evaluation of mental performance and vigilance tested. Program was created consisting of six tasks which test memory, reaction time, coordination of movement and level of sleepiness using the Epworth Sleepiness Scale. The obtained data are stored in a database and will be further processed and analyzed statistically.

A. Database Conception

The database structure was designed so that the information it contained as much information on mental performance and alertness of the patient like time of the test each task, errors in tasks, number of success answer act. To connect to the database through a data adapter Microsoft.ACE.OLEDB.12.0, because the database was created in .accdb format (Microsoft Access). The database is located in the data directory of the program and mirroring to google Drive cloud. [12],[13],[14]

B. Task 1 - Presentation of Words and Their Immediate Equipment

The first task is focused on memory investigated. This task is not determined only number of correctly remembered words, but also the number of poorly remembered and words that said the test more than once. The monitor will gradually appear 30 words (Figure 1). The challenge is to remember what they most. When all the words have tested must equip as many words presented, Regardless of how the order. The memorized words then enter in the text box (Figure 1), which appears after presentation of all 30 words. The role is not limited. Presentation of words is repeated three times. For each repeating the same words appear in the same order as in the first experiment. It is necessary to always insert all remembered the words, including those that were already entered in previous experiments. That we will not only memorized the number of words in each experiment, we also observe whether repeatedly tested remember more words.

Figure 1.Inserting memorized words

C. Task 2 - Sorting Numerical Series

The objective of this task is to sort the numbers 1 to 15 in the fastest time. For this purpose form in which the 15 keys with individual numbers (Figure 2), these buttons are arranged in three rows and five columns. Button sequence is random. When you click on this button right. The button will disappear. This task is not recorded only time during which the test line up correctly series of numbers, but also the number of false clicks.

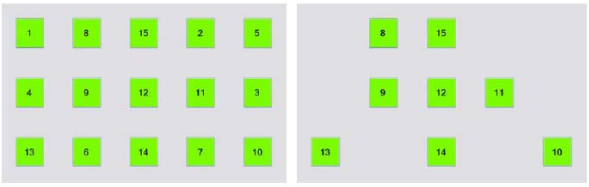

Figure 2. Sorting numerical series

D. Task 3 - Test of the ReactionTtime

This role is based on a psychomotor vigilance test, the test responds pressing the button to light the bulb. In my role appear on the monitor green rectangle, which will be at different time intervals to change color to red (Figure 3). The goalies to click on the rectangle as soon as possible after the color change from green to red. The color varies randomly in the interval 2-10 seconds. Total time jobs are 2 minutes. Do database imposing reaction time individual experiments from which the end of the job calculated average reaction time. An important figure is the number of false clicks, ie. clicks, when the rectangle green.

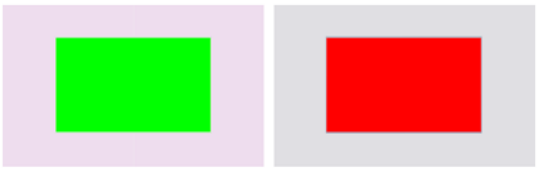

Figure 3.Change the color of the rectangle

E. Task 4 and 5 - Pulling Shapes

These tasks are focused on the coordination of movement. The monitor shows the image Star shaped (Figure 4). The challenge is to shape Stroke clockwise, move the mouse but is reversed - up is down and down is up, left and right direction remains unchanged. Properly trace shape changes color. If you get out of shape, color cursor turns red and must be returned to the place buckling. The task starts ramming of blue point and ends when the entire pattern correctly trace or after 90 seconds. Results in displacement, which trace the test, expressed in percentage. This task is carried out first and then the dominant non-dominant hand

F. Task 6 - Epthword Sleepiness Scale

This questionnaire (Figure 5) measures the general level of sleepiness during the day. Identifies option snap or sleep on a 4-point scale (0 - I'd never take a nap/a, 1 - a small chance nap, 2 - medium chance nap, 3 - high chance nap) in 8 different situations or activities that are part of everyday life. The total score is the sum of ESS points in different situations and can take values from 0 to 24. The database is not saved only the total score, but also the results for each scenario. The results of this task will be taken as a reference in statistical data processing

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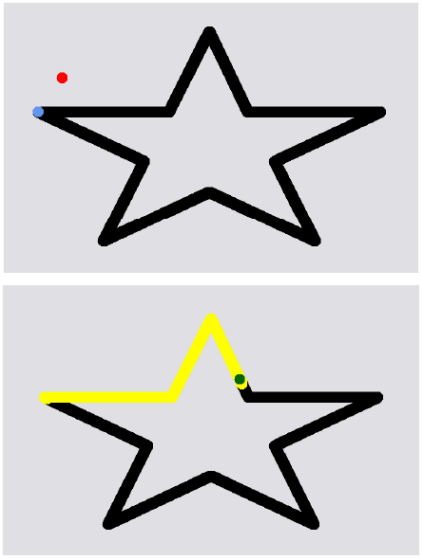

Figure 4. Pulling shapes

III. PROGRAM CONTROL

Program Control for measuring mental performance and alertness is done by tablet or mouse. It was necessary to find a tool that would enable the program to operate even if one not used to working with a mouse. These people could be misrepresented the results of each task. [15],[16]

Tablet was chosen as a compromise between control mouse and implementation of special control. It consists of a solid substrate with an active area of a rectangle and moving the sensing device in the form of a wireless pen. The computer input peripherals allows operate a computer in a similar way as a computer mouse (cursor control).

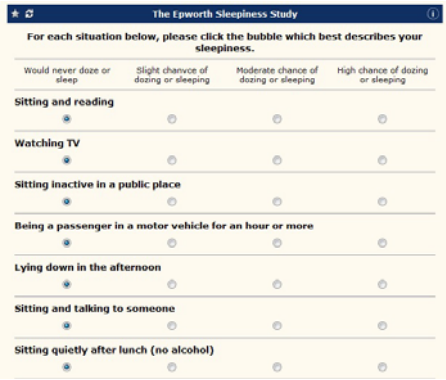

Figure 5.Epworth Sleepiness Scale

To realize the test was elected tablet G-Pen F610 (Figure 6). It is a widescreen tablet with a working area of 150 x 250 mm (6 x 10 „). The computer is connected via an interface USB, from which is also supplied. For their work with the tablet used pressure-sensitive pen, which is capable of recognize the 1024-level pressure for accurate shooting. The pen is cordless and are available there dedicated buttons for left and right mouse button.

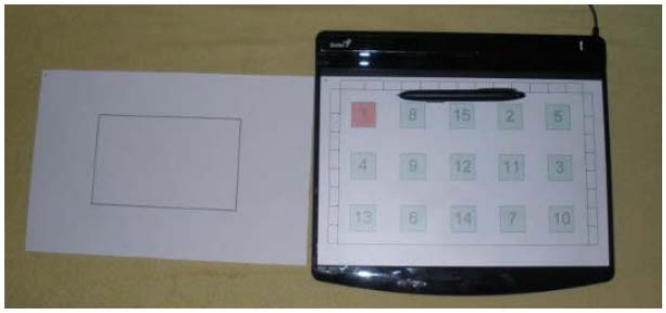

Figure 6. Tablet templates for test

When testing must be used in tablet mode, absolute positioning, the position of the pen on the tablet corresponds to the position of the cursor on the screen. This is adapted to the program, which individual form elements adapt to the screen resolution, and therefore can be used monitors of different sizes and different resolutions. For the role of „Sorting numerical sequence“ and „Test reaction time“ were then created templates (Figure 6), which help better control tasks using a tablet. These templates are inserted top sheet tablet. [17]

IV. STATISTICAL EVALUATION OF MEASUREMENT DATA

Data were obtained using an assay for measuring mental performance and vigilance. Was tested a total of 60 people aged 21 to 28 years. Tested had normal sleep patterns and not been treated with any kind of sleep disorder. The statistical evaluation was used program Statgraphics Plus version 5.0.

A. Analyzed data

Output data in a program objectively measured data showing mental performance and alertness measured entity. These data are classified using variables which serve as input for statistical evaluation.

The same number of men (n=30) and women (n=30) took part in the measurement. Number of tested with dominant right hand is n=51 what creates 85% of all respondents. Number of tasted with dominant left hand is n=9 what creates 15% of all respondents.

The examined group of persons that was selected for this study is the group of young people of age between 20 to 30 years who, in time of the testing, did not suffer from any hypnophrenosis and who had normal sleep habits. 60 respondents of the age from 21 to 28 years complied with this criterion from which there were 30 men and 30 women. Before the intrinsic test completing the tested were asked not to use any drinks with caffeine content, e.g. tea or coffee, and also not to smoke.

Time demand on the test gave rise to the creation of two versions because its length ranges approximately from 20 up to 30 minutes. Therefore, a part of data was collected by means of the first version when the tablet was used for controlling. The rest of data was obtained from the respondents to whom the program was sent by e-mail. The advantage of this version was addressing of a huge number of persons. The response rate was about 50% in this case. [17]

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V. RESULTS

A. The Dependence Between the Total Score and the ESS Sex

The first step of the test according to the total score of the ESS and sex create a Table (Tab. 1), which contains the observed frequency and the relative frequency and the expected frequency. For proper results it is necessary to observe the test assumption that none of the expected frequency of not less than 2 and at least 80% of the expected frequency must be greater than 5. To meet these prerequisites are met, the overall score ESS divided into three categories: 0-6 points, 7-8 points, and 9-24 points.

TABLE I. A FREQUENCY TABLE FOR THE CORRELATION BETWEEN THE TOTAL SCORE AND ESS

	1-6 standart value	***7-8 border value***	***9-24 increased value***
man	14 23,33% 14	7 11,67% 7	9 15,00% 9
woman	14 23,33% 14	7 11,67% 7	9 15,00% 9
Sum	28 46,67%	14 23,33%	18 30,00%

On Table (Tab. 1) is seen that all of the expected frequency of greater than 5, it is possible to use the chi-square test. Before the test still possible the null and alternative hypotheses:

- The null hypothesis is: ESS depend on gender.
- The alternative hypothesis is: ESS depends on sex.

Since the p-value was set to 1, i.e., p-value is greater than 0.05, do not reject the null hypothesis and we can say that the overall ESS scores depend on the sex (of at level 0.05).

B. Correlation Between the Number of Memorized Words and a Total Score of ESS

In this test, we find that the correlation between the number of memorized words on the third attempt and a total score of ESS. ESS scores are divided into three groups of 0-6 points 7-8 points 9-24 points. To determine this dependence, we use ANOVA method by which we can compare the mean number of selections. Must be met assuming a normal distribution and homoscedasticity (ie. The same variance). If you have the same scattering data, but does not come from a normal distribution, we used the nonparametric Kruskal-Wallis test, the mean values do not test, but compliance medians.

First, we formulate null and alternative hypotheses:

- Null hypothesis: Number of memorized words depend on the ESS score.
- Alternative hypothesis: Number of memorized words depends on the ESS score.

Before the test is needed to verify the normality of the data, where the null hypothesis is: The data comes from a normal distribution. For testing normality is used chi-square test of goodness of fit. P-value of 0.031 is the first choice, ie. p-value <0.05, so we reject the null hypothesis and we can say that the data come from a normal distribution. P-value for the second selection is 0.208, ie. p-value> 0.05, so do not reject the null hypothesis and we can say that the data comes from a normal distribution. P-value 0.343 is the third selection, ie. p-value> 0.05, therefore, we accept the null hypothesis and we can say that the data comes from a normal distribution.

Next, we verify homoscedasticity, where the null hypothesis is: Scattering of memorized words all selections are the same. Because the data from the first choice does not come from a normal distribution, use Levene test. P-value is 0.10, ie. p-value> 0.05, do not reject the null hypothesis and we can say that the spread of memorized words all selections are the same.

Because the data from the first choice does not come from a normal distribution, we cannot use ANOVA. To test the dependence use Kruskal-Wallis one-way analysis of variance to test conformity medians. P-value of 0.018. This value is smaller than the significance level of 0.05, so we reject. Analysis of sleep deprivation null hypothesis and accept the alternative hypothesis. We can say that the number of memorized words depends on the total score (ESS at a significance level of 0.05).

For a more accurate conclusion in rejecting the null hypothesis needs to be done post hoc analysis. The maximum number of memorized words are tested with a lower Scores for ESS. The biggest difference in the number of memorized words is tested with ESS between 0-6 and 7 to 8 more homogeneous than the time required to sort the numerical range for the test with ESS 7-8 and ESS 9 to 24 The higher the ESS, the longer the time required to sort the numerical series. The biggest difference time required to sort the numerical series is among tested with ESS 0-6 and 9 to 24

C. Dependence Between the Average Response Time and Overall Score ESS

In this assay, verify whether the relationship between the reaction time and the average total score of the ESS. ESS scores are divided into three groups of 0-6 points 7-8 points 9-24 points. To determine this dependence, we use ANOVA method by which we can compare the mean number of selections. Must be met assuming a normal distribution and homoscedasticity (ie. The same variance). If you have the same scattering data, but does not come from a normal distribution, we used the nonparametric Kruskal-Wallis test, the mean values do not test, but compliance medians.

First, we formulate null and alternative hypotheses:

- Null hypothesis: The average response time does not depend on the total score of ESS.
- Alternative hypothesis: The average response time depends on the total score of ESS.

Before the test is needed to verify the normality of the data, where the null hypothesis is: The data comes from a normal distribution. For testing normality is used chi-square test of goodness of fit. P-value of 0.67 is the first choice, ie. p-value> 0.05, so do not reject the null hypothesis and we can say that the data comes from a normal distribution. P-value is 0.15 second selection, ie. p-value> 0.05, so do not reject the null hypothesis and we can say that the data comes from a normal distribution. P-value of the third selection is 0.45, ie. p-value> 0.05, so do not reject the null hypothesis and we can say that the data comes from a normal distribution.

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Next, we verify homoscedasticity, where the null hypothesis is: Scattering average times of all selections is the same. Because all selections are normally distributed data, use Bartlett's test. P-value is 0.056, ie. p-value> 0.05, do not reject the null hypothesis and we can say that the variance of the average reaction time of selection is the same.

Because all the preconditions are met, we can proceed to the actual ANOVA. P-value is 0.0002. This value is smaller than the significance level of 0.05, so we reject the null hypothesis and we can say that the average response time is dependent on the overall score ESS (at a significance level of 0.05).

D. Dependence Between the Track Trace Non-Dominant Hand and aTotal Score of ESS

In this test, we find that the relationship between the track non-dominant hand and an overall score of ESS. ESS scores are divided into three groups of 0-6 points 7-8 points 9-24 points. To determine this dependence, we use ANOVA method by which we can compare the mean number of selections. Must be met assuming a normal distribution and homoscedasticity (ie. The same variance). If you have the same scattering data, but does not come from a normal distribution, we used the nonparametric Kruskal-Wallis test, the mean values do not test, but compliance medians.

First, we formulate null and alternative hypotheses:

- Null hypothesis: The track does not depend on the total score of ESS.
- Alternative hypothesis: The path depends on the total score of ESS.

Before the test is needed to verify the normality of the data, where the null hypothesis is: The data comes from a normal distribution. For testing normality is used chi-square test of goodness of fit. P-value of 0.0001 is the first choice, ie. p-value <0.05, therefore rejected the null hypothesis and I can say that the data come from a normal distribution. P-value of 0.071 is the second choice, ie. p-value> 0.05, so do not reject the null hypothesis and we can say that the data comes from a normal distribution. P-value 0.343 is the third selection, ie. p-value> 0.05, so do not reject the null hypothesis and we can say that the data comes from a normal distribution.

Next, we verify homoscedasticity, where the null hypothesis is: Scattering tracks all selections are the same. Since the date of first choice does not come from a normal distribution, use Levene test. P-value is 0.59, ie. p-value> 0.05, do not reject the null hypothesis and we can say that the scattering paths all selections are the same.

Because the data from the first choice does not come from a normal distribution, we cannot use ANOVA. To test the dependence use Kruskal-Wallis one-way analysis of variance to test conformity medians. P-value is 0.16. This value is greater than the significance level of 0.05, so do not reject the null hypothesis. We can say that the track trace non-dominant hand is independent of the total score (ESS at a significance level of 0.05).

VI. DISCUSSIONS

The aim of this work was to study methods for the diagnosis of sleep disorders and the creation of a program to measure mental performance and alertness on the basis of which it is possible to determine whether the test suffers from lack of sleep. Was designed and created program stack the six tasks with which testing memory, reaction time, coordinate the movement and level of sleepiness.

There were an average of individual tasks for testing in the range 21 to 28 years who have normal sleep patterns and do not suffer from a sleep disorder. The first task was tested by memory. The average number of words memorized in the first experiment was 10.1 ± 3.1 words, in the second experiment, it was 16.2 ± 3.8 words, in the third 21.0 ± 3.5 words. In the second task was average time required to sort the numerical series 13.8 ± 2.4 seconds. The average reaction time in the third test role was 0.438 ± 0.067 seconds. Percentage tracks trace dominant hand was 70.7% ± 22.5%, when using non-dominant hand, the percentage of paths 69.3% ± 26.0%. The value of total Epworth Sleepiness Scale score was 7.1 ± 3.2.

As a point of reference was chosen Epworth sleepiness scale, the results of which were compared results of the study Dr. Murray Johns, who created this method. Because the results of ESS in this study were comparable to studies, it was possible to use the results for further testing.

In testing, it was found that there is a correlation between the number of memorized words, the time required for alignment of numerical series and the average reaction time and the total score of the ESS. At the same tim the followed track traced of both dominant and non-dominant hand depends on the overall ESS score is strongly.

VII. CONCLUSIONS

Computer aided testing of psychometric variables seems to be very useful in the medical practice and research. Many testing procedures are well-grounded by a simple algorithm and they are suitable for the implementation in a form of the computer software. The software enables a quick and cheap measurement of the psychometric variables.

The effect of the personal UI interaction within device is conclusive for accuracy and reliability of the psychometric evaluation. The classical PC's UI are not very appropriate because of variable computer skills in population. The button device as used in the Cognitive Drug Research Ltd. System is more useful due to its simplicity. Use of pressure-sensed pen and tablet is another interesting way because of almost general writing skills in population.

This method of measuring mental performance and alertness was created in collaboration with the University Hospital in Ostrava. The proposed scheme can be further used for testing and collection of additional data and to determine the average value, characterizing the other groups tested.

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IT-Aided Business Process Enabling Real-time Analysis of Candidates for Clinical Trials

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***Abstract*—Recruitment of participants for clinical trials is a complex task involving screening of hundreds of thousands of candidates, e.g., testing for trial-specific inclusion and exclusion criteria. Today, a significant amount of time is spent on manual screening as improper selected candidates have impact on the overall study results.**

We introduce a candidate eligibility metric, which allows systematic ranking and classification of candidates based on trial-specific filter criteria in an automatic way. It is implemented as part of our web application, which enables real-time analysis of patient data and assessment of candidates. Thus, the time for identification of eligible candidates is tremendously reduced whilst additional degrees of freedom for assessing the relevance of individual candidates are available.

Keywords*-*Clinical Trials; In-Memory Technology; Data Analysis; Eligibility Metric; Clustering.

I. Introduction

The pharmaceutical industry heavily invests in clinical trials to improve existing drugs and introduce new ones every year [1]. The Guidelines for Good Clinical Practice (GCP) define details for conducting clinical trials on human subjects, which are widely adopted in certain countries, e.g., the United States of America (USA) and those of the European Union (EU) [2]. Amongst others, they define document artifacts, e.g., Informed Consent Form (ICF) or Case Report Form (CRF), as well as interaction between involved actors, e.g., investigators, sponsors, and trial participants. Before participation in a clinical trial, candidates need to be tested for certain trial inclusion and exclusion criteria.

In the given work, we introduce an integrated software-aided business process supporting the determination of eligible candidates for clinical trials building an additional source of confidence. Our software addresses principal investigators during the design of clinical trials and investigators during the identification of candidates. Our approach incorporates latest In-Memory Database (IMDB) technology to support real-time analysis of patient data during this phase. As a result, our approach contributes by reducing the overall time for determination of candidates, which consumes a significant amount of the overall clinical trial time today [3]. Figure 1 depicts the result view of our web application with four result clusters while a ranked candidate list for the cluster "desired Karnofsky score" is selected.

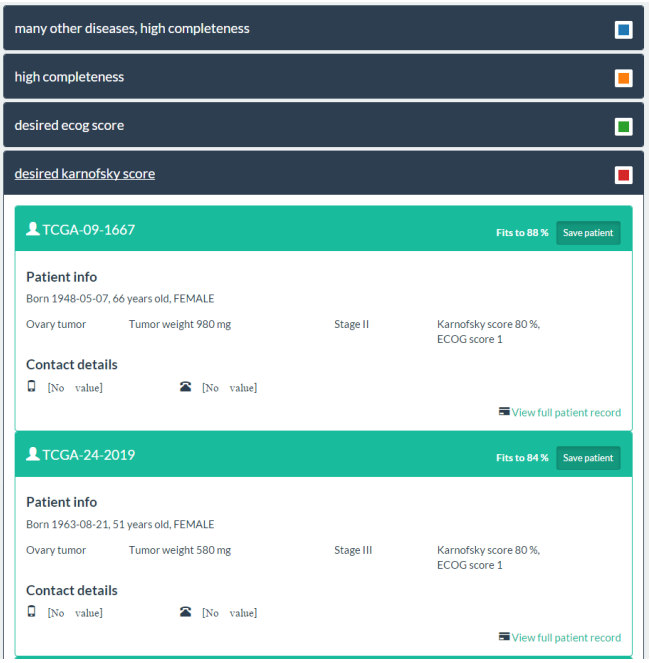

Figure 1: Result view of our web application showing four clusters of candidates each containing an automatically assessed list of candidates for review.

The rest of the work is structured as follows: In Section II, our work is set in the context of related work whilst we share a real-world use case in Section III. We explain our incorporated methodology in Section IV, demonstrate how it can improve the clinical trial process in Section V, and introduce our IMDB approach in Section VI. In Section VII, we discuss our findings and our work concludes with an outlook in Section VIII.

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II. Related Work

The given contribution addresses a) a software solution improving filtering and assessment of patient data and b) a business process integrated the software. Selected related work addressing software solutions for candidate identification are discussed in the following.

The Veterans Health Information Systems and Technology Architecture (VistA) of the U.S. Department of Veterans Affairs is a Hospital Information System (HIS) combining data from distributed VA clinics and sites in a single data source [4], [5]. Although it contains data for candidate identification, it is not used this purpose as it does not provide required tools.

The Informatics for Integrating Biology and the Bedside (i2b2) system provides IT tools for clinical researchers for research purposes [6]. It provides a configurable and interactive query editor supporting a range of filters, including diseases, medications, laboratory tests, and doctor's visit details [7]. Our contribution provides additional enhancements, e.g., an eligibility metric to rank and cluster results, as defined in Section VI.

Dumas et al. identified Acute Myeloid Leukemia (AML) candidates for clinical trials using clinical data from of patients taken from the HIS of a German hospital and compared them to inclusion and exclusion criteria of ongoing clinical trials [8]. We also believe that the secondary use of existing clinical data is beneficial for candidate identification. Thus, our contribution defines an IT-aided business process for candidate identification for a wide range of diseases.

All aforementioned approaches lack support for assessment of results. In contrast, our approach systematically calculates a score for each candidate enabling ranking and clustering of the result set for the first time.

III. Use Case

We defined the following persona as a concrete example for our enhanced business process in the remainder of this work. Forrest G., male, 62 years old was an active smoker for a long period in his life. During one of his regular checkups, he was recently diagnosed with Non-Small Cell Lung Cancer (NSCLC). Now, Forrest worries about receiving the best available treatment for NSCLC. Thus, he learned about targeted therapies and is very interested in participating in clinical trials optimized for his personal disease. As a result, selected details of his Personal Health Record (PHR) are shared in a de-identified way to assess the individual eligibility for clinical trials. We refer to a fictive clinical trial targeting NSCLC requiring at least 150 g available tumor tissue for preliminary testing.

IV. Methods

In the following, we share details about our incorporated methodology: in Section IV-A we introduce our eligibility metric defining a unique key figure per candidate representative for its calculated trial applicability whilst the incorporated IMDB technology to leverage interactive data analysis of big patient data in our software artifact is introduced in Section IV-B.

A. Candidate Eligibility Metric

We define a vector of n candidate criteria $\vec{v} = (c_1, \ldots, c_k, \ldots, c_n)$ with $c_i \in [0,1], i \in \{1, \ldots, n\}$ while each of the vector components is calculated by an individual function, as described in Section VI-E. Thus, each candidate is represented as a point in a n-dimensional vector space where the most suitable candidate is defined by the vector $(1.0, \ldots, 1.0, \ldots, 1.0)$.

We define the eligibility score s_k of a candidate k as the normalized Euclidian distance $d(\vec{v_{1.0}}, \vec{v_k})$ between the vector of the most suitable candidate $\vec{v_{1.0}}$ and the vector of the individual patient $\vec{v_k}$, as defined in Equation 1.

$$s_k = 1.0 - \frac{d\left(\vec{v_{1.0}}, \vec{v_k}\right)}{d\left(\vec{v_{1.0}}, \vec{v_{0.0}}\right)} \quad (1)$$

$$= 1.0 - \sqrt{\sum_{i=1}^{n} \left(\frac{v_{1.0_{c_i}} - v_{k_{c_i}}}{v_{1.0_{c_i}} - v_{0.0_{c_i}}} \right)^2} \quad (2)$$

B. In-memory Database Technology

We refer to IMDB technology as a toolbox of Information Technology (IT) artifacts, which enables processing of enterprise data in the main memory of server systems in real time [9]. Through the combination of IMDB database technology and analysis of available candidate data, we aim to achieve a speedup for the time-consuming identification of candidates, as described in Section I. In the following, selected building blocks of the IMDB technology are introduced.

1) Column-Oriented Data Layout: Most modern relational database systems fall into the category of transactional databases and store their data in a row-oriented format, i.e., all attributes of a record are stored in adjacent blocks. This is advantageous if the complete data of a single row has to be processed. On the other hand, analytical database systems store and process their data column-wise, i.e., all entries of a column are stored in adjacent blocks, which is beneficial if only selected attributes of a data set need to be accessed. When filtering patients based on a study's criteria, only certain parts of their data need to be read. The types of queries to be expected in our prototype can therefore benefit from this data layout.

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2) Lightweight Compression: Lightweight compression refers to a data storage representation that consumes less space than its original pendant [9]. Storing data column-wise facilitates lightweight compression techniques, such as run-length encoding, dictionary encoding, and difference encoding [10]. The diverse nature of patient data results in heterogeneous data, i.e., many NULL values, facilitating the potential to save space through encoding.

3) Partitioning: Our incorporated IMDB provides vertical and horizontal partitioning [11]. The former addresses large database tables and splits up a database table in multiple column-wise subsets that can be distributed on individual servers while the latter divides a long database table in smaller subsets of data [12]. Splitting data into equally long horizontal partitions supports parallel search operations and improves scalability [9]. For our use case, partitioning enables the use of multiple sources of candidates to increase the reach of the system [13].

4) Multi-Core and Parallelization: Modern system architectures are designed to provide multiple CPUs with each of them having separate cores. This capacity needs to be fully exploited by parallelizing application execution to achieve maximum processing speed. Internal tools of IMDBs are implemented to benefit from parallelization. By using the capabilities of our database, we can speed up the process of clustering candidates.

5) Bulk Data Load: For candidate identification, large amounts of clinical data have to be collected and stored. The bulk load capabilities of IMDBs support this through the use of the CSV format and parallel processing of the data to insert.

C. Realistic Patient Data

We consider the use of realistic patient data for development and testing as the foundation to optimize software for real-world use cases. As a result, we incorporate patient data from The Cancer Genome Atlas (TCGA) program in the course of our development [14].

D. Design Thinking

Together with subject matter experts from research and industry, we derived design decisions for our web application and the enhanced process. For that, we incorporated the design thinking methodology, which helped to stratifying the cooperation in an interdisciplinary team [15]. Consequently, we performed regular user interviews sharing our research artifacts to constantly improve our approach.

V. The Clinical Trials Process

We define the following phases in the context of clinical trials as depicted in Figure 2:

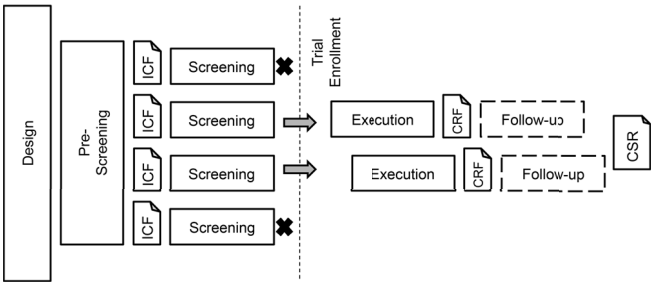

Figure 2: Phases of a clinical trial.

- **Design**: Inclusion and exclusion criteria need to be defined during this phase. Reviewing a list of potential candidates supports investigators in selected criteria to include a representative population.
- **Pre-Screening**: Candidate's data is scanned and they are contacted if they fulfill the criteria listed in the clinical trial synopsis.
- **Screening**: After a comprehensible explanation of the trial's purpose, candidates need to consent their participation by signing the ICF. A doctor, e.g., by conducting medical tests, checks them. Iff a candidate fits all required criteria of the trial definition, she/ he gets enrolled.
- **Execution**: The actual trial execution starts, e.g., intake of pharmaceuticals or placebos. After the participant completes the trial the individual case report is created. The Clinical Study Report (CSR) is created after the overall trial is finished and the trial database was locked.
- **Follow-up**: Study participants are followed up with satisfaction surveys and further assessments, e.g., regular health checks.

A. Design of Study Protocols

Inclusion and exclusion criteria are defined during design of a study protocol to identify adequate candidates representing the population [16]. Improper design decisions may result in complex or inadequate selection of candidates affecting the quality of the study results [17], [18]. Our contribution supports trial investigators, e.g., they can examine all candidates and evaluate defined inclusion and exclusion criteria by simulating their impact on candidate identification using real data.

B. Identification of Eligible Candidates

The analysis of patient-specific data and their matching with study-specific inclusion and exclusion criteria is performed during the pre-screening phase, as defined in Section V. Nowadays, this involves time-consuming and manual analysis of individual trial criteria for hundreds of thousands of candidate profiles.

Our enhanced process improves the manual process by defining an eligibility score for each candidate, as defined

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in Section IV-A, representing the applicability in context of the study. The process consists of the following phases:

- Configuration of filter criteria,
- Automatic analysis of candidate data, and
- Review of results.

During configuration of filter criteria, investigators define criteria accordingly to the inclusion and exclusion of the clinical trial on the filter screen of our app. The specified filter criteria are translated into a database query matching the selected filter criteria.

During data analysis, individual candidate records are screened to meet defined filter criteria. This process is performed completely within the incorporated IMDB, which eliminates the need for any application-level filter and optimizes run time.

During the review phase, the investigator accesses the result screen, which consists of a list of clusters, each of them containing a ranked list of trial candidates with a specific matching score for the current trial. Candidates with a similar score but with different criteria are assigned to individual clusters, which outlines how candidates' criteria differ.

For each candidate, all accessible data can be directly expanded in the result view in order to assess follow-up questions directly during the manual review phase. The result view also provides interactive graphical analysis features using individual criteria, e.g., graphs and figures about age, gender, or tumor weight distribution. If a potential candidate is found, she or he is added to a persisted list of candidates to follow-up, e.g., by downloading the candidate list to inform them about their eligibility for the clinical trial.

VI. Contribution

In this section, we share implementation details of our software application for identification of trial candidates matching trial-specific filter criteria.

A. Database Schema

We defined an extendable star database schema for patient data optimized for data analysis [19]. It consists of the fact table `CLINICAL_PATIENT` containing unique master data about the patients, which is referred to by multiple dimension tables as depicted in Figure 3. For example, the fact table contains birth date, gender, and ECOG or Karnofsky score to quantify the health status of a person [20], [21]. Dimension tables store additional optional patient data using $n : m$ relations, e.g., the dimension table `DRUG` contains details about medication intake, such as duration and dosage.

For our research prototype, we incorporated TCGA data for indications of lung and ovarian cancer and consolidated it. The `LUAD` table contains details about lung cancer, e.g., tumor location or active smoking time, whilst the `OV` table contains ovarian-specific details.

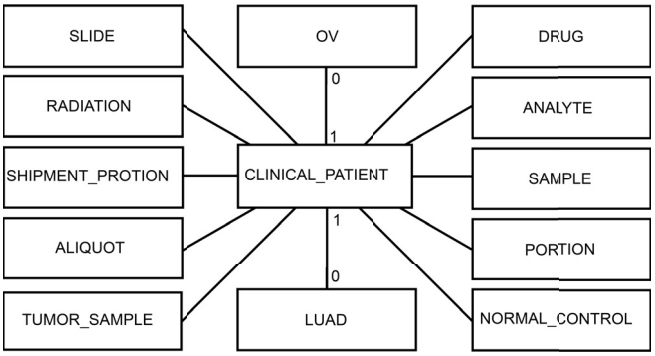

Figure 3: Entity-relationship diagram of our star database schema. It consists of the fact table `CLINICAL_PATIENT` holding general patient data and dimension tables holding additional data, e.g., drug intake or tumor sample. Cardinality of all relations is $1 : *$ unless marked.

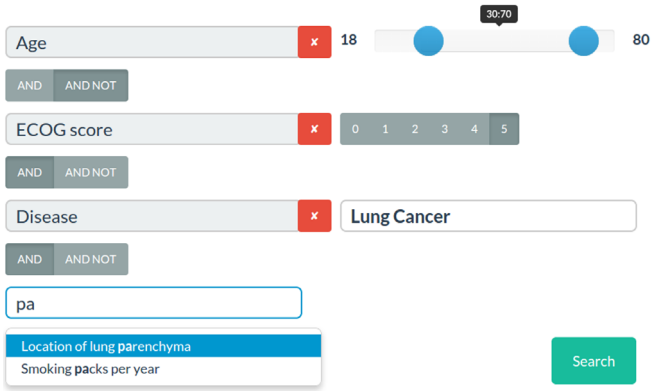

Figure 4: Filter criteria creation in our web application: Three filters have already been created, and the user is creating a forth one using the auto-completion.

We defined an Extract, Transform, Load (ETL) process for import of TCGA data into the database [22]. TCGA is downloaded and divided into multiple raw data files, which are transformed by a Python script into CSV files. The latter is loaded into our database using its bulk load capabilities, as described in Section IV-B5.

B. Backend and Frontend

Our web application backend consists of a lean Ruby server with Sinatra serving the static content of web pages only [23]. All analysis operations, e.g., clustering and ranking, are performed directly within the IMDB, which eliminates the need to transfer data through the application stack. We designed a web application exchanging user data between backend and frontend using Asynchronous JavaScript and XML (Ajax) [24].

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C. User Interface

Our User Interface (UI) incorporates a responsive design, i.e., display optimized for individual device classes, e.g., desktop PCs and mobile devices.

Figure 4 depicts the filter definition view of our web app for the use case defined in Section III. On the left-hand side, inclusion and exclusion filter criteria are specified. Our app provides a list of relevant filter criteria using auto-completion while typing. Filter criteria are added either as Boolean operators `AND` or `AND NOT`. On the right-hand side, filter-specific values are defined.

Figure 6 shows a matrix of user-defined filter criteria for graphical exploration. The color of the dots indicates the cluster, where the value belongs to, e.g., the red cluster indicates candidates that are close to the desired ECOG score while having only a few other diseases. Candidates with a high result from the most suitable candidate function are most eligible from a data's point of view.

Candidates are grouped in similar clusters, where each cluster consists of a ranked list of candidates with specific information. Investigators can inspect all available candidate information with a click on the "View full patient record" link and store them in a follow-up list using the "Save patient" button.

D. Filter Types

Together with subject matter experts, we defined filter types supporting the identification of trial candidates. In the following, selected filter types of our web application are described in detail:

- **Single option filters** can have either of two possible values, e.g., gender: ♀ or ♂,
- **One of many options filters** describe one of multiple statuses, e.g., cancer stages I to IV,
- **Range filters** define a continuum of values, e.g., age between 18 and 45,
- **Threshold filters** must be above or below a certain value, e.g., a minimum tumor weight, and
- **Free-text filters** provide a text field with auto-completion for selection of various values, e.g., diseases or previous medications.

We distinguish hard and soft filters, where the former do not allow outliers and the latter consider incomplete or imprecise data points. Soft filters assign lower scores to outliers instead of removing them completely. If data relevant for a filter is missing, e.g., the tumor weight of a candidate is unknown, s/he will receive a lower score, but will not be removed from the result.

E. Ranking

For candidate ranking, we incorporate our vector-based eligibility metric, as described in Section IV-A.

Table I: EXCERPT OF PATIENT DATA.

Candidate	Gender	Age	Diagnosis	Tumor Weight
1	♂	45	NSCLC	242 g
2	♂	51	NSCLC	n/a

The most suitable candidate has the value one in all components of the vector. For each candidate in the result set, we calculate the distance between the candidate-specific and the most suitable patient's vector. The ranking process is based on the vector space model [25].

For each vector component, an individual function implements the comparison of candidate-specific data with the data defined for the most suitable candidate and returns a decimal value within the interval $[0, 1]$.

Ranking functions for individual filters are implemented differently depending on their type: there are functions for hard and soft filters as well as a special implementation for threshold filters. Apart from filter-specific functions, the completeness and most suitable candidate functions are always executed per candidate.

1) Completeness: Patient data may be incomplete, i.e., some data is missing or unavailable in the candidate's profile. The completeness function assigns a higher score to candidates having all matching attributes available.

Let us consider the excerpt of patient data in Table I for the use case described in Section III. The completeness score is defined as mean of all available attributes, i.e., the number of available and matching facts divided by the number of requested facts. The completeness score is 1.0 for the first and $\frac{2}{3}$ for the second candidate. Thus, the completeness function ranks the first candidate higher than the second, who could still match all trial criteria although the tumor weight is unavailable.

2) Most Suitable Candidate: The most suitable candidate function defines a certain penalty for candidates with additional indications than the requested ones to take eventual issues into account. We defined an individual penalty score for each disease according to the degree of disease, e.g., having lung cancer is worse than having asthma. The score is calculated by subtracting the maximum of all disease penalties from 1.0.

Let us consider the use case described in Section III. NSCLC without any additional indications results in a score of 1.0, a candidate suffering from asthma receives a score of 0.8, and a candidate, who just recently suffered a heart attack, receives a score of 0.5.

F. Calculation of Eligibility Score

Let us consider the use case, as defined in Section III, using the completeness, general health, and threshold functions to define the eligibility score s, as defined in

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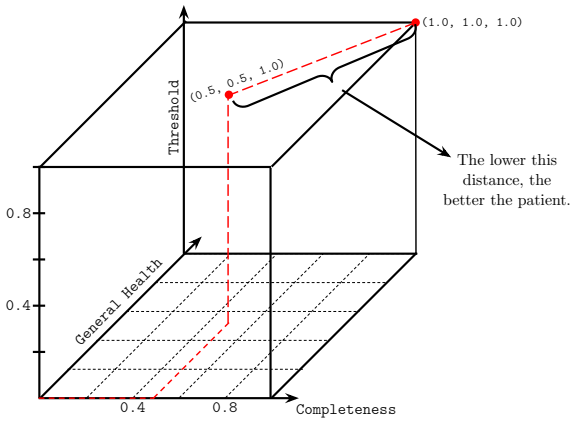

Figure 5: Example of calculating the ranking score for a candidate. The current candidate has the values (0.5, 0.5, 1.0). The most suitable candidate is located at the point (1.0, 1.0, 1.0). The normalized Euclidian distance between the current candidate and the most suitable candidate determines the total ranking score.

Section IV-A. Figure 5 depicts candidate k as $\vec{v_k} = (0.5, 0.5, 1)$ and the most suitable candidate defined by $\vec{v_{1.0}} = (1.0, 1.0, 1.0)$ as well as the distance from each other in the three-dimensional space. For candidate k not all required data is available, the health status differs from the requested one, and the requested threshold value is exceeded. Thus, the eligibility score s_k is $s_k = 0.5918$, i.e., candidate k is eligible for the clinical trial with 59.18% with regard to the selected criteria.

G. Clustering

Ranking candidates enables investigates to evaluate the eligibility of candidates with regard to trial criteria. However, two candidates may vary in different aspects while having the same eligibility score.

Thus, we perform a clustering of results, which assigns similar candidates to the same cluster. We selected the k-means clustering algorithm as it is the most appropriate algorithm for our purpose [26]. Clustering is directly executed within our IMDB, which eliminates the need for exporting the data, processing the data by third-party tools, and importing of results. As a result, we were able to leverage interactive data analysis and exploration of results for our application's end users.

While the target number of clusters must be configured, the algorithm can be applied to any number of dimensions, as the distance to the cluster centroids can be calculated in any multi-dimensional space. For our prototype, we configured the algorithm to return four clusters. This number is configurable and was chosen after consideration of our sample dataset. Because users of our application are allowed to vary the number of filters, the number of dimensions is not fixed.

In the frontend, the resulting list of candidates is grouped in clusters, which are given appropriate names

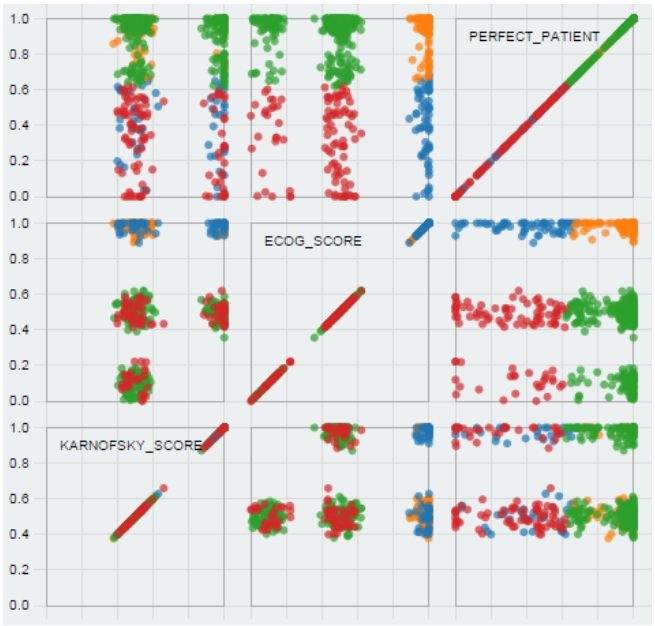

Figure 6: Visualization of multi-dimensional clustering results. Each block shows all candidates, projected onto two dimensions. For example, the bottom right square shows the position of all candidates with regard to Karnofsky score and the most suitable candidate function, as defined in Section VI-E2. Clusters are indicated by a point's color.

based on frequent properties. Additionally, the clusters are visualized in a projection to each pair of two dimensions as depicted in Figure 6.

VII. Evaluation and Discussion

We configured our candidate eligibility metric for a concrete clinical trial addressing lung cancer patients, as described in Section IV-A. Our database was populated with real patient data taken from TCGA including various indications, such as lung cancer and ovarian cancer. Together with our experts from industry, we defined specific filter criteria to retrieve relevant subsets of candidates eligible for the specific clinical trial.

During our conducted user interviews, we received promising feedback that our enhanced business process will reduce the overall time to identify candidates for clinical trials.

Our enhanced process combines the automatic analysis of patient data with a manual review phase performed by a human expert. Thus, routined work is optimized through our software-aided web application while the accuracy of the outcome is guaranteed by the incorporated human reviewer.

VIII. Conclusion and Outlook

In the given work, we shared research results of our interdisciplinary cooperation of pharma experts, clinical

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trial teams, and software engineers. Applying the concrete use case of a clinical trial for lung cancer patients, we defined an enhanced business process incorporating IT artifacts, which enable the integrated analysis of patient data. Today, the identification of candidates requires manual interpretation and matching of patient and trial data, which results in a time-consuming and error-prone process, e.g., in course of phase III and IV clinical trials with more than thousand participants.

We defined a generic candidate eligibility metric in Section IV-A that is configurable per trial to reflect specific inclusion and exclusion criteria of the study synopsis. Furthermore, we introduced an enhanced IT-aided business process for identification of eligible candidates for clinical trials in Section V. Consequently, we shared in Section VI design decisions and implementation details of our web application supporting the analysis of large pools of patient data in real time.

Our future work focuses on the adaption of our candidate eligibility metric to further indications and the use of additional criteria. Furthermore, we are working together with our partners to establish our enhanced process as standard operating procedures for cost-effective identification of candidates for clinical trials.

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Understanding the social dynamics of Twitter, Facebook and Diabetes.co.uk and their value implications for patients and health researchers

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Abstract—**Health and wellness are dominant societal concerns, which is reflected in their presence on Social Media. People with diabetes use a range of Social Media to share information, build knowledge and seek peer support, but surprisingly little is known about how this behaviour varies across platforms. We drew data from a 10 day period in September 2014 from Twitter, Facebook and the Diabetes.co.uk discussion forum and classified these according to their informational and social properties, using Bales Interaction Process Analysis (IPA). Contrary to the generalisations made in previous research, Twitter is chiefly used for information dissemination, whilst Facebook and Diabetes.co.uk are also used for social interaction and peer support. These differences exist due to the structure of these platforms, including the potential for threaded discussions, the specificity of the user base and the presence of a moderator, each of which influence the nature of member interactions. Our novel findings contribute new insight about the social function of different Social Media in healthcare and the relative value of these Social Media as sources of data for health research, tools for health promotion and intervention, as well as forums for community and patient engagement.**

Keywords–health, diabetes, social media, social network, Facebook, Twitter

I. INTRODUCTION

Type 1 diabetes is a chronic autoimmune condition, which occurs when the pancreas stops producing insulin. This results in increased levels of glucose in the blood, putting patients at long-term risk of heart disease, stroke, nerve damage, kidney disease and blindness. There is currently no known cure for Type 1 diabetes and those diagnosed are treated either by insulin injections, insulin pump therapy, islet cell transplantation or a pancreas transplant.

Hamm et al. (2013) concluded that patients most commonly use Social Media as a means of supporting selfcare and that the literature is dominated by studies of online discussion forums and support groups, followed by dedicated social networking sites and micro-blogs [1]. Social Media has become an increasingly popular data source for public health researchers to understand how members of patient communities interact with each other regarding specific conditions [2], [3].

Previous research has focused on single platforms such as Twitter, Facebook or condition specific online communities [3], [4], [5]. We go beyond such studies with a view to gaining insights into the social interactions that occur across and within Social Media. We are not aware of any previously published study to have compared Twitter (twitter.com) Facebook (https://www.facebook.com/T1Diabetes) and Diabetes.co.uk (http://www.diabetes.co.uk/forum/category/type-1-diabetes.19/) in relation to Type 1 diabetes. Motivated by this, we considered the following research questions, the answers to which will help inform the design of future successful Social Media for the purposes of health and will help patients understand better how they can manage their conditions using them:

RQ1: Do diabetes Type 1 patients use different Social Media platforms for different purposes?

RQ2: Which Social Media are successful at encouraging social interaction and support for patients?

RQ3: What are the implications for Social Media design?

Our three Social Media embody different styles of social interaction. Twitter and Facebook are well known, general purpose sites. Diabetes.co.uk is a condition specific discussion forum where users can create content and others can comment.

The rest of this paper is organised as follows. Section II describes the methodology and datasets. Section III describes outcome of RQ1. Section IV describes the outcome of RQ2. Section V describes the outcome of RQ3. Section VI provides a conclusion to close the article.

II. METHODOLOGY AND DATASETS

For our comparison of Social Media use by diabetes patients, we took a two-stage approach: firstly we extracted and screened posts made by 533 users from each of the three sites and then categorised them using the Bales IPA categories.

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Application of Bales Interaction Process Analysis Bales IPA system [6] was first introduced in 1951 and has been widely used in public health research as a means of identifying and recording the nature, not the content, of group interactions. Bales identified and defined twelve categories of group interaction each of which were considered when reviewing the Type 1 diabetes posts. Each post was considered a single unit of interaction and that the categories were not considered mutually exclusive when applied to the sample of posts.

Twitter A random 1% sample of all available Tweets was extracted on the 3 October 2014. The tweets were posted between 0:00:00 (UTC) on 1 September 2014 and 23:59:59 (UTC) on 10 September 2014 and were extracted by crawling the data through the standard publically available Twitter API using the pre-defined search terms *diabetes, type 1 diabetes, t1 diabetes, t1d* and *type 1*.

The data extracted included the date and time of posting in UTC, the Twitter account id and the text in the tweet. Re-tweets were identified and any duplicates and spam were removed. The sample of 1433 English language tweets was manually screened. Those that referred to Type 1 diabetes, produced a sample of 66 posts, which were subsequently included in the categorization stage. url links included in the tweets were not reviewed during the screening.

Facebook Using the Facebook search functionality, we searched for Type 1 diabetes and in doing so identified the largest Type 1 Diabetes Facebook community available. Known as the Type 1 Diabetes Community this community was established in 2011 and is intended to be an open forum for people who have Type 1 diabetes to talk about anything they want. As of 4 October 2014, it had 36,671 likes and on this same date all wall posts and replies that were posted between 1 and 10 September 2014 were identified by viewing the storyline of historical posts. These posts along with the author and the date of posting were manually extracted for further analysis. Given the particular focus of this online community, the sample of 479 posts were all considered relevant to Type 1 diabetes and therefore included in the categorisation stage.

Diabetes.co.uk Diabetes.co.uk is a global Diabetes community with over 125,000 members spanning all forms of the condition. The Type 1 discussion forum on Diabetes.co.uk was identified through the forum homepage and the list of discussion threads was then filtered based on the start date 1 September 2014. All original posts and replies posted between 1 and 10 September 2014, were identified and manually extracted. The total sample of 713 posts was included in the categorisation stage.

Extraction and screening of relevant posts The output of the extraction and screening of Type 1 diabetes posts are summarised in Table 1, where we see the number of posts extracted from each of the three Social Media, the number of original posts and replies included in the sample and their respective number of authors.

III. RQ1: DO DIABETES TYPE 1 PATIENTS USE DIFFERENT SOCIAL MEDIA PLATFORMS FOR DIFFERENT PURPOSES?

Surprisingly, although Twitter had the highest absolute number of total posts at 1433, these results revealed that it is a noisy source of data compared to other Social Media as only 66 posts were relevant to the condition of Type 1 diabetes. Contrary to expectations, the results also revealed that despite being a popular Social Media, Facebook, with a total of 479 posts, was not the most actively used platform for members to discuss the condition. Instead the discussion forum on Diabetes.co.uk was identified as being the most actively used Social Medium included in the study, with a total of 713 posts during the 10-day period.

The sample of Twitter data contained notably fewer responses to posts (0%), than Facebook (96.6%) and Diabetes.co.uk (94.2%). suggesting that there is a greater degree of two-way communication between users of social networks and discussion forums compared to micro-blogging platforms. Twitter has less developed conversational structures, making it harder for patients to read all related comments. Facebook and Diabetes.co.uk posts include associated comments that are easily found. Facebook and Diabetes.co.uk also provided much richer posts, both in terms of length and structured content, i.e. long chains of comments.

When analysing the data further, it was identified that the community moderator who posted questions from anonymous members of community created all original posts within the Facebook community. Thus creating a degree of uncertainty, as the number of authors contributing to original posts is not available This is in contrast to the Diabetes.co.uk discussion forum and Twitter where any registered member of the site could generate an original post and that 37 and 62 members created an original post, respectively.

It was also revealed that a single post within the Facebook community generated a higher response rate relative to others. The post Over/Under time again. 153. Are you over or under? was a request from the community moderator for members to post their current blood glucose levels. This post generated 101 responses, accounting for 21% of the total sample therefore performing a role similar to that of an online survey.

In summary, our results for RQ1 indicate that patients do use different Social Media platforms for different purposes as is highlighted by the volume and conversation structures represented in the sample. Whilst Facebook appeared to be heavily moderated, this was weakly present in Diabetes.co.uk and absent in Twitter. Given these differences in utility it is natural to ask how members of the Type 1 diabetes community use these Social Media to interact with others. Surprisingly, we find that Diabetes.co.uk was the most actively used Social Medium in terms of volume, whilst Facebook achieved the highest percentage response rate. A finding widely known within the Computer Science community but not yet reflected in much of the published Public Health research that is available.

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TABLE I. SUMMARY OF POSTS FROM 1 – 10 SEPTEMBER 2014

Social Media	Sample size	Screened sample size				Posts included in IPA
		N (%) original posts	*N authors*	*N (%) replies*	*N reply authors*	
Twitter	1433	66 (4.6%)	62	0 (0%)	0	66
Facebook	479	16 (3.3%)	1	463 (96.6%)	310	479
Diabetes.co.uk	713	41 (5.7%)	37	672 (94.2%)	123	713

IV. RQ2: WHICH SOCIAL MEDIA ARE SUCCESSFUL AT ENCOURAGING SOCIAL INTERACTION AND SUPPORT FOR PATIENTS?

The results of Bales IPA reveal differences in the nature of interactions between users of these three Social Media. These are described in Table II, where we see the percentage of posts relevant to the Bales IPA categories for each of the three Social Media. The Over/Under post accounted for one fifth of the Facebook sample. It was therefore highlighted as a separate line item so as to avoid potential skew of results within the Facebook dataset.

Whilst the three Social Media are predominantly used to disseminate suggestions, opinions and information with other members, the highest percentage of posts; Twitter (36%), Facebook (44%) and Diabetes.co.uk (55%) represent members sharing their opinion. Noticeably fewer posts ask to receive suggestions, opinions and information from other members and the majority of these are original posts.

We observe several interesting differences in the nature of the posts. As noted, Twitter is mainly used to disseminate information (29%) and opinion (36%) and not for interaction. These posts are characterised by dramatization (18%), few friendly posts (18%) and no indications of agreement or disagreement between members. Below shows some examples of these Tweets.

- 33k kids in canada went #backtoschool with diabetes. it's time to make school a better places for t1d kids.
- sanofi launches mobile game for kids with type 1 diabetes in the uk
- did you know that the character elsa from the movie "frozen" was in part inspired by a child with type 1 diabetes?
- amazing revolution - bionic pancreas which will automatically inject insulin to type 1 diabetes patients
- an open letter to teresa may advice on her type one diabetes

In contrast, the Type 1 Diabetes Facebook community and Type 1 Diabetes.co.uk discussion forum were considered very interactive with friendly posts accounting for 47% of Facebook posts and 46% of posts on Diabetes.co.uk. The Facebook community generated a greater percentage of agreement (12%) and disagreement (5%) compared to the other Social Media. Whilst the posts within the Diabetes.co.uk discussion forum, indicate a higher percentage of tension (12%) and unfriendly posts (3%), particularly in relation to topics such as diet and the new treatments that are available. Limited moderation of this forum has, therefore, enabled a greater diversity of opinion to be represented.

The three most popular discussion threads on Facebook community are listed in below, including the number of replies to the original post.

- Over/Under time again... 153 Are you over or under? (101)
- This may seem like an odd question but I'm more than a little curious if other T1s experience what I do. I get bit by mosquitos all the time. So much more than anyone else I know. Everyone jokes that mosquitos must love me cause my blood is so sweet. I laugh it all off cause it seems ridiculous. However, I also seem to attract bees. Kind of odd huh? I'm curious how many others experience this...if any? (63)
- Just want peoples advice really I'm 22yrs old been t1 diabetic since I was 6trs old I have one child but planning another but can't get my hba1c past 8.5 and the docs won't let me try till it's 7 any tips on how to get it down? I'm on injections novo rapid and levemir, thanks (54)

The three most popular discussion threads on Diabete.co.uk discussion forum are listed in below, including the number of replies to the original post.

- How highly would you recommend eating low carb? I know this is probably a silly question as it has quite an obvious answer! I love my carbs. I love pasta, rice and

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potatoes. In the past, I've tried to take the right amount of insulin to cover this but it's so easy to get it wrong and misjudge it - it also means I can end up taking whopping amounts of insulin! Would you recommend I reduce my carbs? It should make my diabetes easier to manage, yes? (I'm also doing Slimming World so although I've read a little about LCHF, I'm not keen to start eating loads of 'fattier' foods!) (91)

- New Flash Glucose Monitoring from Abbott Bloodless Testing Its arrived and heres a video for all you guys who wanted more info (76)
- LCHF success stories from type 1's I created this thread as a place for fellow type 1 diabetics to share their success stories on the LCHF diet. I know there is a similar thread on the low carb forum but I found that most of the responses were from type 2's, so I thought it'd be nice to have a specific place for us to share experiences and hopefully inspire and learn from each other! (67)

In summary, our results indicate that although the three Social Media are all used to disseminate information about the condition, Facebook and Diabetes.co.uk are also used for social interaction and peer support. These findings provoke controversy as to the validity and application of Twitter as a popular Social Media for gaining insight into Type 1 diabetes and in its use as a means of delivering relevant health interventions.

V. RQ3: WHAT ARE THE IMPLICATIONS FOR SOCIAL MEDIA DESIGN?

Although the three Social Media can be considered a valid source of information about the clinical condition of Type 1 diabetes these platforms should not be considered equal or synonymous as has been the case in previous public health studies. Exciting implications are also revealed into the utility of condition specific Social Media as a potentially more effective means of health promotion and patient engagement.

Studies into the social shaping of technology reveal that technology does not develop according to an inner technical logic but is instead a social product influenced by the conditions of its creation and use [7]. With this in mind, we find that the way Social Media are configured and moderated as well as, through the opportunities that they offer for certain types of interaction [8] can shape the behaviours of Social Media users.

For patients living with chronic and life threatening conditions such as diabetes, different utilities are derived from dissemination directed Social Media such as Twitter than from interactive and community building Social Media such as Facebook and Diabetes.co.uk. These differences in use within healthcare are contrary to the generalisations made in existing public health studies, which extrapolate the findings from a single Social Media. This therefore provides interesting and novel applications for a diverse range of research directions that aim to understand how Social Media are used by patients with other clinical conditions and what effect this has on the use of Social Media for research, health interventions and patient engagement.

TABLE II. APPLICATION OF BALES IPA TO DIABETES POSTS

Social Media	**Bales IPA Categories**					
	Shows tension	***Dramatises***	***Agrees***	***Gives Suggestions***	***Gives Opinion***	***Seems Unfriendly***
Twitter	8	18	0	20	36	0
Facebook	4	5	9	29	33	1
Facebook (minus the over/under post)	4	6	12	37	40	1
Diabetes.co.uk	12	7	5	18	55	3
	Gives info	***Asks for info***	***Disagrees***	***Asks for Suggestions***	***Asks for Opinions***	***Seems friendly***
Twitter	29	8	0	5	6	18
Facebook	33	6	4	1	3	37
Facebook (minus the over/under post)	15	8	5	1	3	47
Diabetes.co.uk	32	10	1	1	6	46

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VI. CONCLUSION

We presented the first results from this unique study on how different types of Social Media are used by patients living with a chronic condition. In doing so we defy popular assumption and conclude that Type 1 diabetes patients use different Social Media platforms for different purposes, with Twitter primarily used by members for information and opinion sharing, with little support or empathy. Whilst Diabetes.co.uk and Facebook, by virtue of their user base, design and self moderating communities are more successful in their utility for social interaction and peer support by those living with this live long condition. These findings have important implications for Social Media and their application in the context of healthcare.

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A Semantic Reasoning Engine for Lifestyle Profiling in Support of Personalised Coaching

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***Abstract*—The aim of this research is to develop a sound methodology enabling the profiling of coachees that are being supported by a lifestyle coach. This profiling is to be useful for the professional coaches to personalize their approach for helping people acquire and maintain a healthier lifestyle. For the coachee profiling, the known relevant factors for a healthy lifestyle are gathered, e.g., sleep duration and activity level. Based on coachee input in a questionnaire, to be filled in with support of the coach, a qualitative profile is generated in terms of food and liquids consumption, physical activity, personality and cardiovascular risk. The modeling and reasoning environment is realized with semantic technologies. We find that semantic technology is an efficient technology for performing user profiling in a digital coaching context.**

Keywords—coachee profile; ontology; Semantic Web; coachee modeling; Jena rules; protégé

I. INTRODUCTION

This research has been performed within a large ARTEMIS EU project WITH-ME [18], which aims to provide a digital coaching platform that continuously monitors, advises and interacts with coachees to help them acquire and maintain a healthier lifestyle. To reduce the variability of coachees, an initial coachee profile is constructed, based on answers to a questionnaire that is filled in by the coachee, together with a personal coach during the first coaching session. The part of the WITH-ME platform that generates an initial coachee profile is technically realized as an ontological model with a reasoning layer. This initial profile is used by the coach to determine the best strategy for helping the coachee acquire and maintain a healthier lifestyle.

Ontologies have been proven to be effective means for modeling user context [1]. Ontologies model concepts and relationships in a high level of abstraction, providing rich semantics for humans to work with and the required formalism for computers to perform mechanical processing and reasoning.

Using an ontology to model a user profile has already been proposed in various applications like web search [9], [12] and personal information management [7]. Up to this point, ontologies modeling user profiles are application-specific. Namely, each one has been created specifically for a particular domain. Taking into account the continuing incorporation of ontologies in new applications, there is an emerging need for a standard ontology to model user profiles. Such a standard ontology would facilitate the communication between applications and will serve as a reference point when profiling functionalities need to be developed.

In this work, however, we present an ontology for modeling coachee profiles in the domain of medical services including a variety of areas such as patient care, clinical and administrative decisions, assisting devices and patient diagnostics. The developed ontology will be put to use in a web-based software application that accepts input data from a form-based interface and then presents a coachee profile in the field of healthcare. The ontology development process starts with the requirements analysis phase where concepts, attributes, relationships and axioms are identified. In the design phase, a consistent conceptual model is defined over a set of tasks, which increases the complexity of the ontology step by step. In the development phase, a suitable ontological language is used to formalize the ontology, which can help to update the ontology according to the domain concepts in the maintenance phase.

In the remainder of this paper, we first discuss related work for applying ontologies in the medical domain (Section II). Then, we discuss a number of practical issues one can encounter during the creation of an ontology (Section III). Finally, we describe the software and results in some detail (Section IV). The paper ends with a conclusion (Section V).

II. RELATED WORK

Generally, an ontology is defined as a formal, explicit specification of a shared conceptualization [13]. An ontology describes the concepts and relationships that are important in a particular domain, providing a vocabulary for that domain as well as a computerized specification of the meaning of terms used in the vocabulary [13]. The aim of an ontology is to formalize domain knowledge in a generic way and to provide a common understanding of a domain, which may be used and shared by applications and groups. An ontology is also an emerging technology for knowledge representation [14], with applications for reasoning to infer new knowledge, and with applications for data integration [15].

An ontology consists of classes, properties and individuals. A class defines a concept; individuals realize a class; individuals are linked to each other via properties; individuals are linked to data values via properties. The use

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of the term "individual" might seem confusing, since in natural language, it refers to a person. However, in the remainder of this paper, we will use "individual" consistently to refer to an instantiation of a class in an ontology.

Ontological technology has been widely adopted in the business and scientific communities as a way to share, reuse and process domain knowledge. Ontological technology is also central to many applications in fields including information management, systems integration and semantic web services [16]. Many studies have also demonstrated that ontologies are essential for the development of knowledge-oriented systems.

The most widely used terminology resources in the biomedical domain are the Gene Ontology and the Unified Medical Language System. The Gene Ontology (GO) project [19] is a collaborative effort to address two aspects of information integration in several domains of molecular and cellular biology. Namely, the GO project provides consistent descriptors for gene products in different databases and standardizes classifications for sequences and sequence features. The Unified Medical Language System (UMLS) [21] is maintained by the U.S. National Library of Medicine in order to facilitate the development of computer systems in the field of biomedicine and health. The UMLS consists of files and software that bring together many health and biomedical vocabularies and standards to enable interoperability between computer systems.

Huang et al. [4] developed a medical ontology to serve as the foundation for an intelligent Chinese Medical Diagnostic System (CMDS), which acts as a human expert to diagnose a number of digestive system conditions including stomachache, vomiting, hiccups, diaphragmatitis, diarrhea, dysentery, constipation, jaundice, tympanites, etc. In [5], Bouamrane et al. presented the design and implementation of an ontological knowledge-based pre-operative assessment support system, which is a generic clinical screening process, intended to identify early in a patient's journey the potential risk of complications during or after surgery. Juarez et al. proposed in [13] an ontology-based medical knowledge base called the Causal and Temporal Knowledge Acquisition (CATEKAT2), which provides physicians with a broad spectrum of medical knowledge. Kola et al. developed an ontological knowledge base to drive an Occupational Health Application (OCHWIZ), which provides suggestions as to possible causes and industries associated with a given clinical finding related to a specific occupation [15]. Based on these suggestions, it is also capable of inferring other diseases and conditions to watch out for. Alexandrou et al. described an ontological software platform SEMPATH, which can offer personalized treatment plans by using and managing health care business processes (clinical pathways) [14]. During the execution of clinical pathways, the system considers the patient's clinical status and reaction to the treatment scheme according to the Semantic Web Rule Language (SWRL) [29] rules in reconfiguring the next treatment steps.

Other important works with clinical relevance are SNOMED Clinical Terms (CT) [22] and ISO/EN 13606 Electronic Health Record (EHR) communication paradigm [23]. SNOMED CT [20] provides a consistent information interchange and is fundamental to an interoperable electronic health record. It allows a consistent way to index, store, retrieve, and aggregate clinical data across specialties and sites of care. It also helps in organizing the content of EHR systems by reducing the variability in the way data is captured, encoded and used for clinical care of patients and research. EHR Archetypes are formal and standardized specifications for the representation and organization of clinical information inside electronic health records. ISO/EN 13606-2 incorporates the "openEHR" archetype approach as a standard information model, and an exchange representation, for the communication of electronic health record archetypes [23].

III. ONTOLOGY CREATION ISSUES

A. Application Context

The goal of this research is to develop an application capable of generating a complete and qualitative lifestyle profile based on the input of a coachee. An initial ontology model together with the reasoning layer implemented in SWRL has been conceived and validated as a part of the Master Thesis work of Sara Mikolajczak at the KU Leuven, Belgium.

Lifestyle can be modelled taking into account different aspects, e.g., eating and drinking habits like calorie and nutrient intake, activity levels, body and weight levels like BMI (Body Mass Index), WC (Waist Circumference) and WHR (Waist-Hip Ratio), levels of motivation and levels of general (un)healthy habits (risk factors) like smoking and sleeping habits.

To collect the relevant factors that influence a healthy lifestyle, an extensive study of the literature [16][17] has been performed as part of a master thesis. From this literature study, important life style areas have been extracted with relevant data, such as boundary values and possible conditions that may be the consequence of exceeding these boundaries. These data have been used in the construction of the coachee profile.

For some areas, it was not possible to find scientifically validated specifications of the boundary values. In this case, non-scientific values were used to provide a full proof-of-concept implementation. Therefore, further research is required to refine these values in order to provide a correct and justified tool to the coach and coachee.

B. Definition

An ontology is a "hierarchal structuring of knowledge about concepts by sub-classing them according to their properties and qualities" [6]. It can also be defined as "a declarative model of a domain that defines and represents the concepts existing in that domain, their attributes and the relationships between them" [2][6]. Thus, our lifestyle ontology gives a formalization of concepts (e.g., person, habit, motivation) in their respective classes (e.g., Person, Habit, Motivation) and the relations (e.g., is a Person, has a

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Habit, has a Motivation) that can exist between them. A correct definition of classes is very important for data sharing and knowledge representation.

C. Classification

Ontologies can be classified according to the level of detailed knowledge they provide. Upper ontologies provide very generic knowledge with low domain specific knowledge. For example, a disease ontology is an upper ontology compatible for any biomedical domain. General ontologies represent knowledge at an intermediate level of detail independently of a specific task. Domain ontologies represent knowledge about a particular part of the world, such as medicine, and should reflect the underlying reality through a theory of the represented domain. Finally, ontologies designed for specific tasks are called application ontologies.

D. Description

We have defined an ontology as a specification and formalization of concepts and relations between them. The domain concepts are represented by "classes". The features of a concept are described by "properties". These properties can be either relationships between classes, or data values of "individuals", which are the instantiations of a class. Together with these "individuals", this is what constitutes the domain knowledge base.

Classes are the main focus in an ontology. Classes can be sub-classed to describe more specific features of a class. For example, if we define a class Habit, it includes all the habit classes in the habit domain. The Habit class can be sub-classed to specify more specific habits like ConsumptionHabit or SleepingHabit.

Properties can be created to describe properties of a class or individual. For example, we can define a property of a class named "hasSleepingHabit", which connects a Habit Class to the SleepingHabit class. An individual that instantiates the SleepingHabit class can have a property sleepingHabit, which holds a data value that gives the amount of hours somebody typically sleeps. We can also mention that it is possible to store a data value range as a property of an individual, e.g., sleepingHabit could contain a range of the amount of hours somebody sleeps. Moreover, fuzzy logic reasoners can be applied to optimally leverage the concept of a range.

Figure 1 shows a summary of the above discussion. The description of an ontology domain includes [3]:

- The definition of a concept in the domain as classes.
- The definition of an instantiation of the class as individuals.
- The definition of attributes of classes or individuals as properties.

E. Ontology structure

The ontology model contains three ontologies in layers: a Core Ontology Layer, a Profiling Ontology Layer and a Reasoning Ontology Layer. They are depicted in Figure 2.

1. *Core ontology* – is the main ontology, which contains the classes and properties. It also contains a Standard_Profile, which is an individual that contains the boundary values that were recorded during the literature review phase.
2. *Profiling ontology* – contains multiple individuals that describe different parts of the final coachee profile. The final coachee profile is divided into an "eating and drinking profile", a "motivation profile", a "physical profile" and a "health profile". These four aspects are discussed in some more detail below.
3. *Reasoning ontology* – This layer contains the individuals that are to be populated with coachee data.

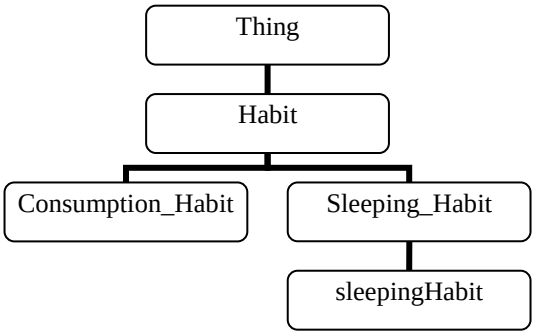

Figure 1: The amount of hours that a coachee habitually sleeps is stored in the ontology.

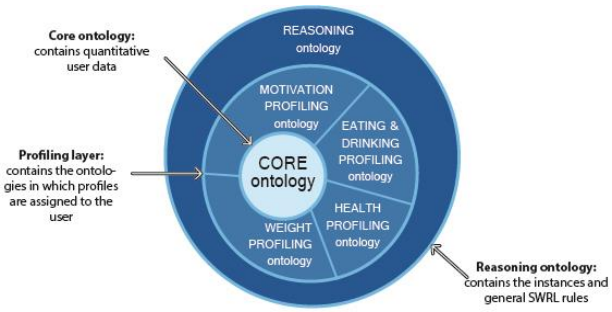

Figure 2: Ontology structure.

Below, we discuss in some more detail the four aspects of the Profiling ontology layer:

Eating and Drinking Profile - In this part of the ontology, the daily consumed food is evaluated. The evaluation of calorie intake is based on the daily calorie requirement (DCR), which in turn is based on the activity level in combination with the basal metabolic rate (BMR). The evaluation of protein, fat and carbohydrate intake is based on the recommended rate of each nutrient in the total amount of calories.

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Motivation profile - Based on answers given on a list of multiple choice questions, the coachee receives a score for being intrinsically and extrinsically motivated. The reasoner evaluates these scores and returns an optimal approach for motivating the coachee.

Physical profile - The physical profile is further split into two parts: the first part concerns the body profiling, the second part the activity profiling. The body profile consists of a body mass index level, a waist-hip ratio level and a waist circumference level. These levels indicate a risk for a cardiovascular disease, given a certain BMI, WHR and WC. The activity profile contains five activity levels going from "sedentary" to "extremely active". The assignment of an activity level to a coachee is based on the her job(s), hobbies and means of transportation.

Health profile - In this part of the ontology, the sleeping and smoking habits are modeled. The optimal daily number of hours of sleep is defined according to certain age categories, e.g., the optimal number of daily hours of sleep for younger people is higher than for older people. The smoking habit class is defined by the daily amount of tobacco products being consumed.

F. Rules

Two formalization approaches for expressing rules have been investigated in this paper. First, the Semantic Web Rule Language (SWRL) can be used to create rules in an ontology. The SWRL is a proposed language for the Semantic Web that can be used to express rules as well as logic by combining Web Ontology Language (OWL) Description Logic (DL) or OWL Lite with a subset of the Rule Markup Language. Second, rules can also be implemented in the format specific for Apache Jena [28], which is a Java-oriented system for handling ontologies. Jena provides an Application Programming Interface (API) to extract data from and to write to Resource Description Framework (RDF) [24] graphs. Since the syntax of Jena rules is more readable, and since these rules can be more easily integrated in a software production environment, we preferred the Jena approach over the SWRL approach.

One can see below a rule that is written in Jena syntax. This rule calculates the DCR of a coachee. DCR is the amount of calories the coachee should eat in a day to maintain her current weight at the current height and age. It is calculated based on the coachee's level of Basic Metabolic Rate (BMR) and how active the coachee is:

```
[DCR:
        (?p rdf:type core:Person)
        (?p physical:hasActivityProfile ?activityProfile)
        (?activityProfile physical:activityValue ?activityValue)
        (?p core:hasExternalExaminationResult ?BMRCalc)
        (?BMRCalc core:examinationType 'BMR')
        (?BMRCalc core:externalValue ?BMR)
        product(?activityValue, ?BMR, ?DCR)
        (?p core:hasExternalExaminationResult ?DCRCalc)
        (?DCRCalc core:examinationType 'DCR')
        -> (?DCRCalc core:externalValue ?DCR)
]
```

IV. DESCRIPTION OF SOFTWARE AND RESULTS

The software implementation that we used to build a proof-of-concept for the WITH-ME project [18] adopts a decoupled architecture, where the evaluation of the data values by the ontology and its rules is strictly separated from the web-based interface. These two components communicate via a so-called messaging system, where the output of the first component (the interface) becomes the input for the second component (the ontology and rules).

The web interface contains a number of questions that need to be filled in, some of which are depicted in Figure 3.

The decoupled architecture of the web-based software requires that the data, i.e. answers to the questionnaire, from the web-based interface is communicated to the separated ontology processing backend. To communicate between these two components, a shared message format is used, i.e. Java Script Object Notation (JSON) [25]. JSON is a lightweight data-interchange format, that is easily readable for humans, and easily generated and parsed by machines. The messaging system that is being used in WITH ME is Microsoft Azure Service Bus [26].

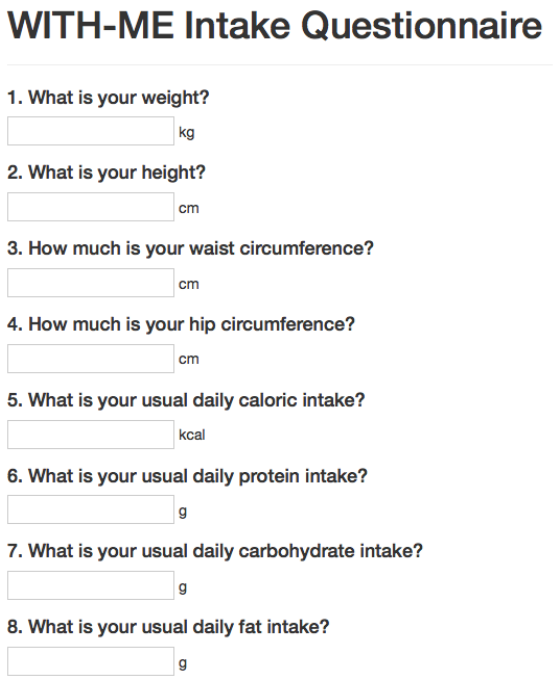

Figure 3: A screenshot of the web-based questionnaire interface.

The collected personal data are sent to the backend, which consists of a Apache Jena implementation around the ontology. The backend accepts the input data and stores them as properties in the appropriate individuals of the ontology model. A Pellet reasoner [27] is then used in the developed system. Pellet is an open-source Java-based OWL 2 reasoner. The Pellet reasoner analyzes the received data from the web system and generates newly inferred data. The inferred data together make up the coachee profile. The output of the backend is again a JSON message, which is

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being submitted to the messaging system. From there, it can be picked up by another decoupled component that could, as an example, generate visualizations of the coachee profile.

The proposed profiler will be evaluated on multiple coachees during the pilot phase of the WITH ME project, starting September 2015.

V. CONCLUSION AND FUTURE WORK

This paper has presented an approach for designing a semantic reasoning engine for coachee profiling. An ontological approach to knowledge representation in healthcare has been selected in the coachee profile design.

The developed system uses a web-based interface for collecting coachee data and an ontology to analyze and process the entered coachee data. The performed analysis generates a coachee profile as a result. This profile can be used to optimize the coaching activities of a professional lifestyle coach, or as a basis for the creation of other software applications that expand the applicability of the developed one. For the former, an example is that a professional lifestyle coach can choose a motivational style on the basis of the motivation profile that is generated by the profiler. For the latter, an example is that a software application can use the profile to automatically recommend objectives to the coachee, on the basis of objectives of other coachees with similar user profiles.

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Detection and Classification of the Basic Emotions Using a Multimodal Approach for Emotions Detection

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***Abstract*—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. On one hand, this paper presents a new method for the fusion of signals for the purpose of a multimodal recognition of eight basic emotions, on the other hand, it present a classification of these basic emotions in three emotional classes, namely, neutral, positive and negative emotions which are using physiological signals. After constructing an emotion data base during the learning phase, we apply the recognition algorithm on each modality separately. Then, we merge all these decisions separately by applying a decision fusion approach to improve recognition rate. The experiments show that the proposed method allows high accuracy emotion recognition. Indeed, we get a recognition rate of 81.69% under some conditions.**

Keywords*— *Signal fusion method; basic emotions; multimodal detection; physiological signals.

I. Introduction

Historically, emotions had a great impact on our behavior, our feelings and we are constantly trying to manage our emotions as well as the people that surround us, in order to live together in harmony. Indeed, emotions enable us to communicate with our environment but also to adapt, to innovate, to succeed, and to flourish.

A lot of research based on video application or speech analysis [9][10] (EMOTIENT, Eurospeech, Nice Speech) has emerged to analyze emotions, with the aim, amongst other, to provide a real-time, aggregate view of users feelings and in general to identify customer dissatisfaction. The solution proposed in this article targets the healthcare domain in that it monitors biological signals, but in a non-intrusive manner for the benefit of patients.

In the future, emotion detection tests will be very challenging because they constitute a key point to analyze the impact of all medical treatments, and the resulting device market will probably be substantial. We should also note that neurodegenerative diseases are characterized by the presence of cognitive and behavioral disturbances, gradually resulting in a loss of autonomy for the realization of acts of the daily routine. These disturbances can fluctuate over time, making the evaluation sometimes difficult with the usual clinical tools. Non-pharmacological approaches for their daily care must be favoured, as pharmacological approaches are time-consuming and involve a significant financial cost as they require a qualified professional entourage who are regularly sought. In this context, the use of new Information and Communication Technologies (ICT) can improve both clinical assessment techniques, but also non-medicated therapeutic techniques. Monitoring patients requires, amongst other, being able to assess their emotional state. The information produced is an aid for the diagnosis and the applicability of medical treatments.

Indeed, new technologies benefiting people's health have emerged and have allowed, for example, developing the bases of affective computing, defined by Rosalind Picard in 1995 [8]. This is an area which aims to study the interactions between technology and emotion to give machines the ability to understand, to interpret our emotions, or even express emotions. Affective computing offers many advantages such as the battle against depression, interactive games, E-Learning, etc.

Our goal is to collect the physiological signals of a person under different conditions of real life to detect emotions automatically. We propose a method for a multimodal detection of emotions using physiological signals. The paper is structured as follows. In Section 1, a brief state of the art on the multimodal recognition of emotions and different methods to merge signals is described. In Section 2, all the steps of the proposed methods are explained in detail; in Section 3, a comparison is made between our results and those obtained in the state of the art; finally, conclusion and future work are reported in Section 4.

II. State of the art

Emotions detection systems are based on three fundamental steps: acquisition of the signals, features

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extraction of these signals and the emotions detection. Many works were focused on the emotions detection using facial expressions, vocal expressions or physiological signals [14][15][16]; however, fewer studies are focused on the multimodal recognition [2] of emotions. The use of a multimodal approach allows not only enhancing the recognition rate but it gives more strength to the system when one of these modalities is acquired in a noisy environment [3]. In theory, there are three methods [12] to merge the signals from various sensors: fusion at the signal level (fusion of physiological signals), feature level fusion (fusion of features) and decision level fusion (fusion of decisions) [4][5].

1) Fusion of signals [4]: This fusion is performed on raw data directly (as shown in Figure 1) from each physiological signal sensor; it can be applied only when signals are similar in nature and have the same temporal resolution. This technique is, therefore, rarely used on account of the difficulty of merging the different signals and the noise due to the sensor's sensitivity.

Figure 1. Signals level fusion

2) Fusion of features [5]: This fusion method (see Figure 2) is most frequently used; it aims at forming a multimodal vector from features vectors extracted for each sensor. It has the advantage of requiring only a single learning phase and the resulting feature vector is multimodal. Otherwise, all descriptors must be synchronized and the treatment is done without taking into account the interactions that may exist between the various parameters.

Several techniques have been proposed in the literature

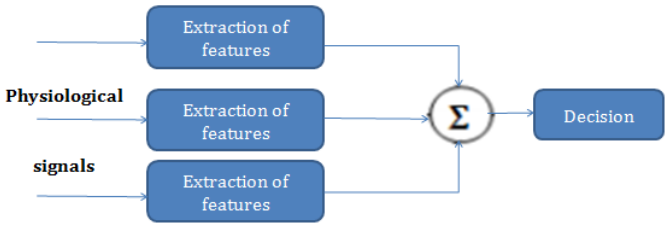

Figure 2. Characteristic level fusion.

[6][7], notably the concatenation of unimodal features vectors, the method of K-Nearest Neighbors (KNN) [17], the Analysis Principal Component (ACP) [8] etc. Fission and Fusion based Hilbert Huang Transform (HHT) features consist in the extraction from Intrinsic Mode Function (IMF) by applying the Empirical Mode Decomposition (EMD) [13].

o Fission: We extract 2 features: instantaneous frequency and amplitude using the Hilbert transform on each IMF.

o Fusion: We determine the use of weighted mean frequency, and the mean instantaneous frequency.

This technique of fusion based HHT features (fusion of 4 physiological signals) has allowed to have a 62% recognition rate while MIT's hybrid method Sequential floating forward search - Fisher projection (SFFS-FP) allowed to have an 83% recognition rate. Nevertheless, the SFFS-FP method allows to determine emotions during a fixed time interval, therefore it does not permit an instantaneous detection. The SFFS-FP method, based on a scenario, calculates the characteristics of a given emotion, and then reduces the number of characteristic data, which enables emotions detection over a long period but not instantaneously. Unlike MIT's method that does not permit an instantaneous emotions detection, our method allows automatic and instantaneous detection of emotions.

In the following section, we focus our study on the instantaneous detection of emotions.

3) Fusion of decisions: After having classified separately from each sensor signals, this is a way to merge these different decisions in order to obtain a global vision of the emotion. Unlike features level fusion, this fusion technique is independent of the nature of the low level features used for decision making [4].

The most used and most intuitive technique is to take

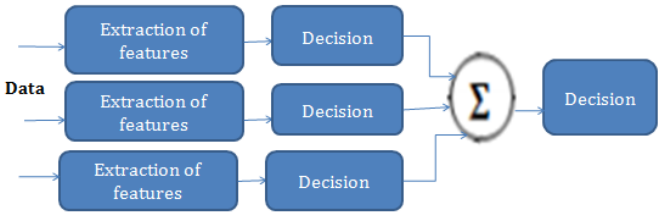

Figure 3. Decision level fusion.

into account for the vote all modalities (each sensor: ElectroMyoGram (EMG), ElectroCardioGram (ECG), Galvanic Skin Response (GSR),Blood Volune Pulse (BVP)), and to choose the decision expressed by the maximum of modalities; Figure 3 shows the steps for this technique.

III. Methodology

In this section, we present a new multimodal and automatic method of emotions recognition based on the fusion of the above decisions. Our method is divided into two major phases, namely: the Learning phase and the Detection phase.

A. Learning phase

This phase consists of four steps (signal splitting, filtering, feature extraction, creation of the basis for learning) in order to provide a learning base which will then be used in the detection phase for the automatic detection of emotions. Figure 4 shows the synoptic of the learning phase.

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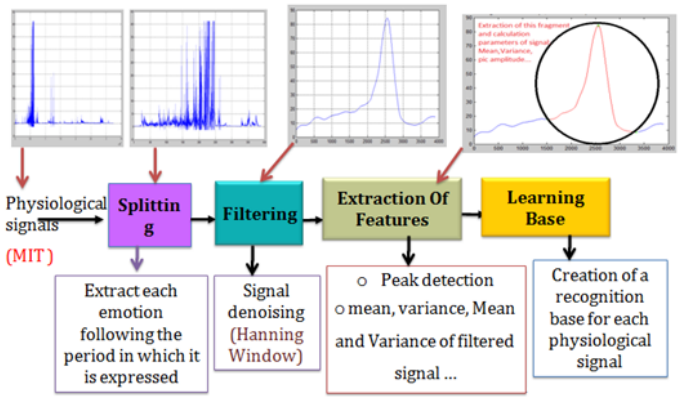

Figure 4. Synoptic of the learning phase.

1) Signal splitting: In this step, after having acquired the physiological signal (here we use the physiological signals provided by MIT [1]), we isolate the part of the signal corresponding to a given emotion because we have information on the period in which each of the eight emotions is expressed. Therefore, this step divides the input signal into eight portions of signal corresponding to eight emotions.

2) Filtering: After having isolated the signal, we filter it to remove the noise of the useful signal, which will facilitate the extraction of the features. We have opted for the convolution method for filtering, which consists in convoluting the signal in the spatial domain with different filters (for which we chose the Hanning filter [8]). This method is less computationally expensive in calculations.

3) Extraction of features: For each isolated and filtered signal, we proceed to the detection of peaks, which is done by calculating the gradient of the signal and then, finding the sign changes in the gradient, because it is rare to find points in discrete signals where the gradient is zero. A maximum is shown by the passage of a positive gradient to a negative gradient, a minimum by the passage of a negative gradient to a positive gradient. To detect and isolate a peak, our method should detect a minimum followed by a maximum followed by a minimum. Once a peak is isolated, we calculate a feature vector composed of five features that are: the mean, the variance, the mean of the filtered signal, the variance of the filtered signal, and the amplitude of the peak.

4) Creation of the Learning phase: After extraction of the features vectors, we create a learning base for each modality. Thus, at the end of this step, we get 4 learning bases which are made of 30 vectors for each emotion, resulting in a total of 240 features vectors. 40% of the signals available for each modality were used for the creation of the learning base and the remaining 60% were used for detection (test).

B. Detection phase

Our research is based on that of Imen [8], which has developed a new vector method to represent emotions. Therefore, each emotion is written as a linear combination of the 8 basic emotions (B) we considered. Indeed, each emotion e can be written as: (B)= (No emotion, anger, hate, grief, love, romantic love, joy and reverence)

$$(e) = \sum_{i=1}^{8} < E, u_i > u_i \quad (1)$$

$$(e) = \alpha_1 * NoEmotion + \alpha_2 * Anger + ... + \alpha_8 * Reverence \quad (2)$$

$$(e) = (\alpha_1 \ \ \alpha_2 ... \ \ \alpha_8)_B \quad (3)$$

where $(\alpha_1, \alpha_2, ..., \alpha_8)$ are the probabilities of the feature vector extracted belonging to each emotional class of our base. This phase consists of two steps. The first step consists in the extraction of features, requiring the same steps as in the learning phase, without going through the splitting step since in this phase, there is no information beforehand on the period at which every emotion is expressed.

The remainder of our process will be based on this features extraction step. It is necessary to detect a peak (an emotional activity) before pass to classification step. Indeed, thanks to this condition on the necessity of detecting an emotional activity, our method allows an instantaneous recognition of emotions. The second step is classification, the purpose of which is to predict the emotional class of the features vector extracted using our learning base, which was developed in the learning phase. We opted for the classification using the K-Nearest Neighbors (KNN) algorithm, which is based on the calculation of the Euclidean distance between the extracted feature vector, the emotional class of which is to be predicted, and 30 features vectors, which are found in our learning base. This allows determining the K nearest emotions in our database of extracted feature vector. Studies [8] have shown that the optimal value of K = 10 and the size of the Hanning window n = 500 enable the best detection. For example, in our algorithm, at the classification stage, among the K = 10 Nearest Neighbors, we have 6 elements belonging to the anger emotional class, 3 elements belonging to the grief emotional class and 1 element to the hate emotional class. Thus, the resulting emotional vector is:

$$(e) = 0.6 * Anger + 0.3 * Grief + 0.1 * Hate \quad (4)$$

where the coefficients (**0.6, 0.3, and 0.1**) are the probabilities of the feature vector extracted belonging to each emotional class of our base. Of this emotional vector, we keep as a final decision the most likely emotional class (the anger class in the above example).

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1) Fusion method of signals through voting: In this section, we studied 2 voting techniques of formalisms which are (i) that consisting in calculating the vector average of the monomodal emotions vectors [19] and (ii) that consisting in making a choice among all the monomodal decisions [19].

o(i) The first technique consists in constituting a matrix (of size 4*8 because we have 4 modalities and 8 emotional classes in our case) made up of the emotional vectors for each modality. We calculate the average of this matrix, which gives us a vector average from which we choose the most probable emotional class. This technique is a better measurement of the center around which the values of the probabilities of each emotional class for each modality tend to concentrate. However, it does not allow a detection of the most probable emotional classes.

o(ii) In the second approach, starting from each monomodal vector, we take the most probable emotional class. Thus, we will have as many decisions as there are modalities (in our case, we have 4 decisions). The final decision will be the class having been decided by the maximum of modalities. This allows one side to take the most probable partial decisions for each modality, and on the other hand, it allows a measure of the central tendency as in the first technique. We opted for this technique on account of the two advantages that we have just enunciated.

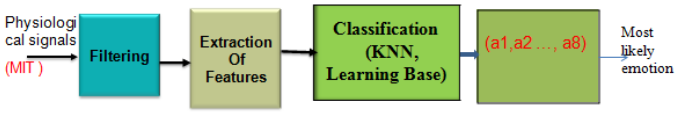

Figure 5. Synoptic of the detection phase for each modality.

Figure 5 shows the different steps in the detection phase for each of the modalities before the mixing step (fusion of decisions).

Our objective being thereafter to put these algorithms in mobile devices which do not have a great memory size, it is thus necessary to set up simple algorithms. That is the reason why we chose this fusion approach on the decisions level. It is simpler and more intuitive than the two others. For example, if we decide on the anger class for the EMG modality, the grief class for the EDA modality, the anger class for the BVP modality and the hate class for the RESP modality, in the step of fusion, we will choose the emotional class of anger which in this case is the class voted by the maximum of modalities.

IV. Results

For these results, we use as data base the signals provided by the MIT [1]. This physiological data collection, the process of which is well described in [1], was carried out on an actor during 32 days for a period of 25 minutes per day, with a sampling frequency of 20 Hz. For this collection, four physiological sensors were used: sensor for the blood volume and pulse (BVP), the pace and volume of respiration (RESP), the electromyography (EMG), and the galvanic skin response (GSR). During this collection, eight emotions were taken into account, which are "no emotion, anger, hate, grief, platonic love, romantic love, joy and reverence" and every emotion was maintained for three to five minutes per day. The results obtained by our algorithm when the unimodal recognition of emotions approach is used are grouped on the histogram below. This approach allows having a mean recognition rate of 57.24%.

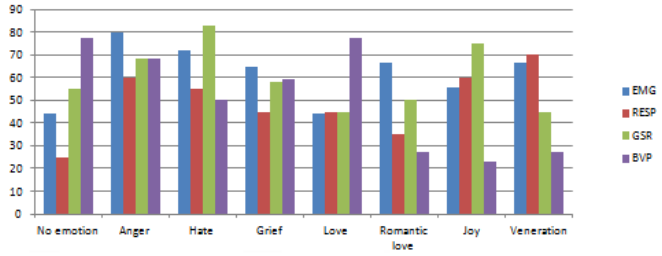

Figure 6. Monomodal recognition rate.

As observed in Figure 6, certain emotions are better detected with certain modalities than others. Indeed, the BVP modality allows to better detect the "no emotion" and "love" emotions, while the GSR modality better detects the 'hate' and 'joy' emotions. The EMG modality rather allows a better detection of the emotions "anger" and "romantic love". This characteristic of modalities is very important because it will allow putting weight on each of the modalities, depending on whether it can better detect an emotion or not for the purpose of a more efficient detection. Subsequently, we have expanded our method to the multimodal approach to increase the emotion recognition rate. Indeed, this multimodal approach allowed having a recognition rate of 81.69%, which is a considerable improvement of the recognition rate compared to the monomodal approach which presented a recognition rate of 57.24%.

Table I. RESULT OF MULTIMODAL APPROACH

Emotion	*Accuracy in % (EMG,GSR,BVP,RESP)*
No Emotion	78.89
Anger	90.11
Hate	88.89
Grief	74.45
Love	72.25
Romantic Love	71.18
Joy	83.33
Veneration	94.44

The results grouped in the Table 1 show a good average recognition rate. Furthermore, we note that our method allows to detect each of the eight emotions with a good recognition rate, where the minimum of 71.18% is obtained for the emotion "Romantic Love "and the maximum is obtained for the emotion" Veneration "with

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a good classification rate of 94.44%. Table 2 allows doing a comparison between our results and the different results of the methods of the state of the art that allow an instantaneous detection of emotions. The method we have

Table II. COMPARISON OF RESULTS

Methods	*Good recognition rate in %*
Method of Kim [11]	61.2
Fusion based HHT features [13],[8]	62
Baseline [8]	71
Proposed Method	81.69

proposed allows a better classification of emotions than all the other methods found in table 2. Statistics demonstrate that approximately 150 million people suffer from a major depressive disorder at any moment, and almost a million commit suicide each year [18]. In fact, neurodegenerative diseases like Alzheimer, that are considered like a cognitive deficiency are caused and/or are source of negative emotions. However, detecting and classifying emotions depending on whether they are negative or not can be used as a means of preventing depression and on the other hand, it may also be used to help health professionals who work with people with cognitive deficiencies. Based on this important observation, we then decided to put in place a strategy of classification of the emotional vector in three emotional classes using the multidimensional model mathematical proposed by Imen [17]. The three emotional classes we have are:

- Neutral emotions : No emotion, Reverence
- Positive emotions : Love, Romantic love, Joy
- Negative emotions: Anger, Hate, Grief

As we mentioned in the previous section, every emotion can be written as a linear combination of other emotions, and using the algebraic representation method of emotions described in [17], from the representation of an emotional vector, representation of the basic emotions is described by a vector containing a single coefficient non zero. For example

$$E_{grief} = (0\ 0\ 0\ \alpha_4\ 0\ 0\ 0\ 0)_B \quad (5)$$

$$E_{joy} = (0\ 0\ 0\ 0\ 0\ 0\ \alpha_7\ 0)_B \quad (6)$$

where $\alpha_4 \neq 0$ and $\alpha_7 \neq 0$

By combining these two vectors of basic emotions, one can get a complex emotion defined as an emotion composed of more than one emotion.

$$E_{combination} = E_{grief} \oplus E_{joy} = (0\ 0\ 0\ \alpha_4\ 0\ 0\ \alpha_7\ 0)_B \quad (7)$$

So, based on this algebraic representation, our classification method is described as follows: For each modality, after detecting an emotional vector which consists of 8 eight basic emotions that each of them will be represented in the form of the (5), combining these vectors to have three emotional classes in the following way:

$$E_{NeutralEmotion} = E_{NoEmotion} \oplus E_{Reverence} \quad (8)$$

$$E_{PositiveEmotion} = E_{Love} \oplus E_{RomanticLove} \oplus E_{joy} \quad (9)$$

$$E_{NegativeEmotion} = E_{Anger} \oplus E_{Hate} \oplus E_{Grief} \quad (10)$$

Subsequently, we use the decisions level fusion proposed for a multimodal classification of emotions. As we note

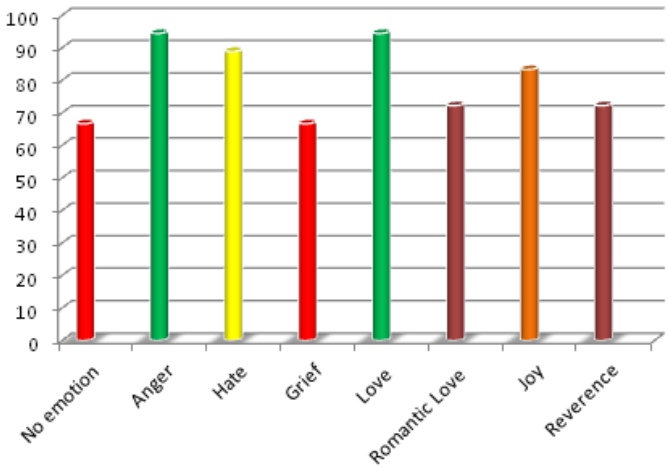

Figure 7. Classification recognition rate.

on Figure 7, our method allows us to have a satisfactory classification rate of emotions. The minimum rate of 66.67% correct classification is obtained for the emotions (**No emotion and grief**) while we obtained a maximum of 94.44% for emotions (**Anger and Love.**)

V. Conclusion and perspectives

We have developed a novel method of multimodal recognition of emotions based on the processing of physiological signals. The physiological signals of 4 modalities were used for the recognition of 8 basic emotions. A new method for multimodal recognition based on the fusion decision level has been defined and developed. On the other hand, a classification method of emotions in three emotional classes has been proposed. The different results show a marked improvement in the recognition rate of emotions. In our future work, on one hand, we will study physiological signals acquisition platforms in order to generate our own recognition base and on the other hand set up a complete system from the acquisition of physiological signals for the detection of emotions. Moreover, this system will allow creating a more appropriate recognition base for a wide range of people.

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