WEARABLE eHEALTH SYSTEMS FOR PERSONALISED
HEALTH MANAGEMENT
Studies in Health Technology and Informatics

This book series was started in 1990 to promote research conducted under the auspices of the EC programmes Advanced Informatics in Medicine (AIM) and Biomedical and Health Research (BHR), bioengineering branch. A driving aspect of international health informatics is that telecommunication technology, rehabilitative technology, intelligent home technology and many other components are moving together and form one integrated world of information and communication media.

The complete series has been accepted in Medline. In the future, the SHTI series will be available online.

Series Editors:
Dr. J.P. Christensen, Prof. G. de Moor, Prof. A. Hasman, Prof. L. Hunter, Dr. I. Iakovidis, Dr. Z. Kolitsi, Dr. Olivier Le Dour, Dr. Andreas Lymberis, Dr. Peter Niederer, Prof. A. Pedotti, Prof. O. Rienhoff, Prof. F.H. Roger-France, Dr. N. Rossing, Prof. N. Saranummi, Dr. E.R. Siegel and Dr. Petra Wilson

Volume 108

Recently published in this series
Vol. 106. G. Demiris (Ed.), e-Health: Current Status and Future Trends
Vol. 105. M. Duplaga, K. Ziełniński and D. Ingram (Eds.), Transformation of Healthcare with Information Technologies
Vol. 104. R. Latifi (Ed.), Establishing Telemedicine in Developing Countries: From Inception to Implementation
Vol. 103. L. Bos, S. Laxminarayan and A. Marsh (Eds.), Medical and Care Compunetics 1
Vol. 102. D.M. Pisanelli (Ed.), Ontologies in Medicine
Vol. 100. I. Iakovidis, P. Wilson and J.C. Healy (Eds.), E-Health – Current Situation and Examples of Implemented and Beneficial E-Health Applications
Vol. 99. G. Riva, C. Botella, P. Légeron and G. Optale (Eds.), Cybertherapy – Internet and Virtual Reality as Assessment and Rehabilitation Tools for Clinical Psychology and Neuroscience
Vol. 97. M. Nerlich and U. Schaechinger (Eds.), Integration of Health Telematics into Medical Practice
Vol. 95. R. Baud, M. Fieschi, P. Le Beux and P. Ruch (Eds.), The New Navigators: from Professionals to Patients – Proceedings of MIE2003

ISSN 0926-9630
PREFACE

The first International Workshop on New Generation of Wearable Systems for eHealth took place in Lucca, Italy, 11–14 December 2003. It is a significant milestone in the dissemination and promotion of this new multidisciplinary area which is expected to play an important role in the evolving health care and health delivery sector, in Europe and world-wide.

The management and coordination of healthcare throughout the entire range of services, from primary to tertiary care, are undergoing fundamental changes such as, more emphasis on prevention and education of users, new ways of delivering care, integrated disease management, empowerment of individuals to manage their own health and overall provision of efficient and cost-effective services. The incentives arising from the need to optimise the use of healthcare budgets and provide quality services and equal access, contributed to the significant development of health telematics, telemedicine and eHealth during the last 15 years.

Extraordinary achievements in science and technology e.g. genomics-proteomics, micro- and nanotechnology, mobile communications, human-computer interface and knowledge management offer for the first time the possibility for new approaches in health, healthcare management and services provision. This includes solutions to support personal health monitoring, early warning and timely intervention, lifestyle management and remote collaboration with health professionals. Daily life activities support and risk management for elderly people and chronic patients can also benefit by these ongoing technological developments.

The new generation of wearable personal eHealth systems has to be affordable, user-friendly, “invisible”, autonomous in terms of power consumption and able to assist individuals in their own health management. Major challenges are ahead such as further research and development, user acceptance and trust, cost effectiveness and business models. Intelligent Biomedical Clothing and biomedical sensors are becoming major driving forces for cutting edge developments. The synergy and close collaboration of all involved disciplines and sectors is of paramount importance.

The workshop on New Generation of Wearable Systems for eHealth was designed to fit the need of the international research community to share advances and brainstorm on future activities in the field. This book has its background in the workshop, and includes full papers describing developments and trends all over the world in the areas of smart wearable monitoring and diagnostic systems, smart treatment systems, biomedical clothing and smart fibres and fabrics. It also covers non-research aspects such as citizens’ and patients’ needs, interoperability, risk management and market perspectives. The chapters mirror the workshop and are preceded by a short executive summary which highlights the main issues, findings and conclusions for the convenience of the reader.

The participation of the major actors involved in research, development, decision making and business should make this book unique and a pioneer in the field.

The Editors
Dr. Andreas Lymberis
Prof. Danilo De Rossi
Message from the organizers

The 1st International Workshop on “New Generation of Wearable Systems for eHealth” is a unique event focusing on smart personal health management through synergies among diverse engineering and research fields e.g. biomedical, telecommunications, software, and textile.

It follows up and consolidates the workshop organised in Brussels in April 2002 by the European Commission, to brainstorm on the thematic area of Intelligent Biomedical Clothing for preparation of the 6th R&D Framework Programme of the EC.

The main goal of the workshop is to report and promote progress in cutting-edge research, disseminate information and facilitate cross-fertilization and collaborations.

The second goal is to provide awareness to users, health providers and other stakeholders. The programme emphasises the immense progress of technologies and their contribution to reconfigure health provision in individual and community level. Great constraints in healthcare budgets, needs for patient consent, acceptance and privacy, major breakthrough in user-friendly, fault tolerant and cost-appropriate technologies are also key factors that necessitate in-depth analysis. The sessions and the round table are build in a way that major problems relating to smart wearable and implantable health systems are presented and discussed in order to seek solutions by involving researchers, industrials and decision makers from several specialities and sectors.

On behalf of the organising team I would like to thank all those who worked so hard to make this event successful. Special thanks are addressed to the workshop collaborators, the European Commission, IEEE-EMB, IEE and AIIMB, as well as to the sponsors, Philips Research Medical Division, M-Wear Team, CSEM and Messe Frankfurt.

Prof. Danilo de Rossi  
On behalf of the organisers
Acknowledgments

The Editors want to thank all authors for their contribution to this book, and Stavroula Maglavera and Andriana Prentza for drafting the minutes from the various sessions which were helpful for producing the sessions’ executive summaries. The Editors are grateful to Francoise Hannecart for the support in the editing of the papers. Special acknowledgment is addressed to Silas Olsson for his continuous support and advice for the improvement of the book.
This page intentionally left blank
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>v</td>
</tr>
<tr>
<td>Message from the organizers</td>
<td>vi</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>vii</td>
</tr>
<tr>
<td><strong>Keynote Address</strong></td>
<td></td>
</tr>
<tr>
<td>Health in the Information and Knowledge Economy Age – A European</td>
<td>1</td>
</tr>
<tr>
<td>Perspective</td>
<td></td>
</tr>
<tr>
<td>Rosalie Zobel</td>
<td></td>
</tr>
<tr>
<td>**I. Introduction to User Needs, Technological Concepts and Market</td>
<td></td>
</tr>
<tr>
<td>Trends</td>
<td></td>
</tr>
<tr>
<td>Executive Summary</td>
<td>7</td>
</tr>
<tr>
<td>New Concepts and Technologies in Home Care and Ambulatory Monitoring</td>
<td>9</td>
</tr>
<tr>
<td>A. Dittmar, F. Axisa, G. Delhomme and C. Gehin</td>
<td></td>
</tr>
<tr>
<td>MyHeart: Fighting Cardiovascular Disease by Preventive Lifestyle and</td>
<td>36</td>
</tr>
<tr>
<td>Early Diagnosis</td>
<td></td>
</tr>
<tr>
<td>Josef Lauter</td>
<td></td>
</tr>
<tr>
<td>Health0: A New Health and Lifestyle Management Paradigm</td>
<td>43</td>
</tr>
<tr>
<td>Akshay Mohan and Rosalind Picard</td>
<td></td>
</tr>
<tr>
<td>How Wearable Technologies Will Impact the Future of Health Care</td>
<td>49</td>
</tr>
<tr>
<td>Rick Barnard and J. Timothy Shea</td>
<td></td>
</tr>
<tr>
<td><strong>II. World-Wide Technical Overview</strong></td>
<td></td>
</tr>
<tr>
<td>Executive Summary</td>
<td>59</td>
</tr>
<tr>
<td>Optimizing Workflow and Knowledge in Healthcare through Innovation</td>
<td>61</td>
</tr>
<tr>
<td>Karl-Jürgen Schmitt</td>
<td></td>
</tr>
<tr>
<td>I-Wear for Health Care and Wellness – State of the Art and Future</td>
<td>70</td>
</tr>
<tr>
<td>Possibilities</td>
<td></td>
</tr>
<tr>
<td>Dirk Hoeffe and Stefan Mecheels</td>
<td></td>
</tr>
<tr>
<td>Research in Intelligent Biomedical Clothing vs. Realities in the</td>
<td>75</td>
</tr>
<tr>
<td>European Textile Business</td>
<td></td>
</tr>
<tr>
<td>Lutz Walter</td>
<td></td>
</tr>
</tbody>
</table>
Current and Future R&D Activities of the EC-IST Programme in eHealth
Jean-Marie Auger and Andreas Lymberis 81

Interactive Textiles for Warrior Systems Applications
D. Paul Leitch 88

Challenges of Ambulatory Physiological Sensing
Jennifer Healey 95

Driver Monitoring – New Challenges for Smart Sensor-Based Systems
Sonja Hermann 103

Market Research on Garment-Based “Wearables” and Biophysical Monitoring and a New Monitoring Method
Claudia Schultze and Stacey Burr 111

III. Smart Wearable Monitoring and Diagnostic Systems

Executive Summary 121

New Paradigms in Telemedicine: Ambient Intelligence, Wearable, Pervasive and Personalized
Paul Rubel, Jocelyne Fayn, Lucas Simon-Chautemps, Hassein Atoui, Mattias Ohlsson, David Telissson, Stefano Adami, Sébastien Arod, Marie Claire Forlini, Cesare Malossi, Joël Placide, Gian Luca Ziliani, Deodato Assanelli and Philippe Chevalier 123

The LifeShirt: A Multi-Function Ambulatory System Monitoring Health, Disease, and Medical Intervention in the Real World
Paul Grossman 133

Body Area Network – A Key Infrastructure Element for Patient-Centered Telemedicine
Thomas Norgall, Robert Schmidt and Thomas von der Grün 142

Contact Centers, Pervasive Computing and Telemedicine: A Quality Health Care Triangle
Nicos Maglaveras 149

Research and Development of Smart Wearable Health Applications: The Challenge Ahead
Andreas Lymberis 155

On-Body Diagnosis for Wearable Systems Serving Biomedical Needs
Jean Luprano 162

Communication and Interoperability for Serial Comparison in Continuous Health Care – The New Challenges
Christoph Zywietz 172
Wireless Body Area Networks for Healthcare: The MobiHealth Project
Aart Van Halteren, Richard Buls, Katarzyna Wac, Nicolai Dokovsky,
George Koprinkov, Ing Widy, Dimitri Konstantas, Val Jones and
Rainer Herzog

Development of Electronic Textiles for U.S. Military Protective Clothing
Systems
Carole Winterhalter, Justyna Teverovsky, Patricia Wilson, Jeremiah Slade,
Brian Farell, Wendy Horowitz and Edward Tierney

IV. Smart Wearable and Implantable Disease Management Systems

Executive Summary

Wearable and Implantable Monitoring Systems: 10 Years Experience at
University of Ulster
E.T. McAdams, J. McLaughlin and J. McC. Anderson

Artificial Kinesthetic Systems for Telerehabilitation
Danilo De Rossi, F. Lorussi, E.P. Scilingo, F. Carpi, A. Tognetti and
M. Tesconi

Implantable Medical Devices: Current Status and Future Developments within
the Healthy-Aims Project
Diana Hodgins

The Role of Implantable Sensors for Management of Heart Failure
Kadir Kadhiresan and Gerrard Carlson

EvoCare: A New Standard in Tele-Therapy
Mark Johanni, Daniel Tietze, Robert Setz and Achim Hein

V. Biomedical Clothing

Executive Summary

e-Health and Quality of Life: The Role of the Wearable Motherboard
Sungmee Park and Sundaresan Jayaraman

Wearable System for Vital Signs Monitoring
Rita Paradiso, Gianni Loriga and Nicola Taccini

Telemonitoring of Vital Parameters with Newly Designed Biomedical
Clothing
R. Baghai, S. Vaysse and A. Blinowska

Strain Sensing Fabric for Hand Posture and Gesture Monitoring
F. Lorussi, A. Tognetti, M. Tesconi, P. Pastacaldi and D. De Rossi
Health in the Information and Knowledge Economy Age – A European Perspective

Rosalie ZOBEL 1
Components, Sub-Systems and Applications Directorate, DG Information Society,
European Commission, Brussels, Belgium
Email: Rosalie.Zobel@cec.eu.int

Abstract. The health sector today faces great challenges. Health is an information-intensive sector where Information and Communication Technologies (ICTs) could significantly contribute to efficiency and productivity gains. European Union is looking at the different facets of eHealth and mainly at the following three:
a) Research and development, in particular to support the development of several regional health information networks, telemedicine services, and personal health systems for patients and citizens.
b) Regulatory framework and standardisation, which ensure competition, interoperability and, at the same time, the confidentiality of personal data.
c) Promotion of eHealth best practices through various eEurope 2002 and 2005 initiatives.

After the pharmaceutical and radiology industry, eHealth is now the third industrial pillar for health. This emerging sector forms the backbone for the reengineering of health systems. It actually improves the access to and quality of care and places citizens at the very centre of its concern.

1. Challenges of the Health Sector

All European countries are currently trying to find ways to sufficiently address the challenges the health sector faces. The citizens demand more efficient and responsive health care services. However, this can not be easily done without significant increases in operational costs.

The recent economic slowdown in conjunction with the ageing problem does not leave enough space to the policy makers for significant increases of the health budgets. With a considerable rise in average life expectancy gains 2 and with more citizens passing this critical age threshold the required public finances for covering healthcare costs have been in steady increase.

The problems, thus, is how to improve the quality of the provided healthcare services without increasing the costs in a challenging social and economic environment. Infor-

1The views developed in this paper are that of the author and do not reflect necessarily the position of the European Commission
2According to the projections of the United Nations, OECD countries are likely to experience increases of between 3 and 4 years in the life expectancy of their populations up to 2030 (OECD, 1998). It is anticipated that rates of growth in numbers of people passing the age of 80 across OECD countries average to 70 per cent (OECD, 1995). In addition, persons aged 80 and over are the heaviest users of medical care.
Information and Communication Technologies (ICT) have proven to contribute to the productivity gains of institutions and the consequent reduction of the related costs. ICTs are used already with great success for administrative and healthcare purposes. However, as the ICTs are becoming smaller, faster, wireless and remotely controlled, new opportunities are being created for new medical tools and systems. Recently, the Internet and the web have opened up new opportunities for improving the response time of health care services and simultaneously reducing the costs (e.g. through telediagnosis).

As the penetration of PCs and the Internet in Europe is increasing, a critical mass of general practitioners and users for the provision of online health care services is being created. Eurobarometer surveys have showed a steady rise in the rate of Internet connections by general medical practitioners. The 2002 survey showed that, on average, 78% of EU medical general practitioners were connected to the Internet, with 100% connected in the UK and 98% in the Nordic countries. The use of the Internet to deliver patient care is also growing. On average, 48% of medical practitioners use Electronic Health Care Records and 46% use the Internet to transmit patient data to other care providers for the purposes of continuity of care. However, a fully interactive use of the Internet to deliver care to patients through the provision of, for example, e-mail consultation (12%) or allowing patients to book appointments on line (2%) appear to be in its early stages.

It becomes evident that we are at the early stages of a new era that will completely change the way the healthcare services are/will be offered. Significant efforts should be devoted to the research, development, promotion, and diffusion of new eHealth services and technologies. According to a study realised by Deloitte & Touche, the eHealth or Health Telematics sector is becoming the third industrial pillar of healthcare area after the pharmaceutical and the medical (imaging) devices industries. It is estimated that the health expenditure on ICT systems and services would rise from 1% in 2000 to 5% by 2010, and that the market would offer reliable and affordable personal health systems assisting citizens to manage their lifestyle.

2. The eHealth RTD Activities

The last ten years the eHealth³ activities of the Directorate General, Information Society at the European Commission have funded through several Framework programs (e.g. Telematics and Information Society Technologies) innovative research and developments actions in several areas. The final goal of these activities is to contribute to the Lisbon Strategy through RTD in intelligent environments that enable ubiquitous management of citizens’ health status and assist health professionals in coping with major health challenges.

2.1. Vision

The main vision behind these activities is to improve access, quality and cost efficiency of health care services through innovative ICTs by

- delivering health care services online to reduce unnecessary duplicate examinations and waiting queues,

³Official Web Site of the eHealth Unit: http://www.cordis.lu/isti/directorate_c/ehealth/index.html
enabling patients to participate, with better knowledge and responsibility, in the processes of care and rehabilitation, through intelligent monitoring systems as well as through relevant and personalised health information,

• developing an intelligent environment that enables citizens to manage their wellbeing through access to qualified sources of health information and active participation in illness prevention,

• providing health professionals with access to timely relevant information at the point of need, new tools for better management of risk and systems to acquire up-to-date biomedical knowledge and facilitating health authorities to manage properly the on going reorganisation of health delivery systems.

• fostering co-operation of health care providers at regional, national, and European level

2.2. Research and Innovation Activities

The focus of research and innovation activities of the eHealth activities is the implementation of the 6th RTD Framework programme and more specifically to develop, contribute and promote to the following activities:

• smart and wearable biosensor technology (intelligent clothing and textiles) and implants that interact and communicate with other systems and health points of care for the ubiquitous monitoring of health status leading to better management of well being and improved disease prevention and treatment of patients,

• ICT systems supporting health knowledge management, interoperability of health information sources, medical ontology, clinical guidelines development, and method for decision support and risk analysis, evidence based medicine and risk management,

• knowledge in the areas of medical informatics, bioinformatics and neuro-informatics that enable disease prevention and therapy and tools enabling the individualisation of diagnoses and treatment,

• initiatives that help create the European Research Area (ERA) in the field of eHealth by co-operating with related initiatives, programs and policies of Member States
In addition to the above, dissemination of best practices and implementation issues are also being supported through:

- active contributions to major non-research policies such as eEurope and regional policies, such as supporting the eHealth action plan for eEurope 2005
- implementation of FP5 activities by exploiting synergies between projects and external activities, by disseminating achievements and by maximising impact.
- co-ordination and interaction with other European Commission services involved in activities related to eHealth
- promoting international collaboration both with developed countries in order to support standardisation, assessment and market creation as well as with developing countries to best benefit from the proven technology.

2.3. eHealth activities within the eEurope Action Plan

The focus of the eHealth activities within the eEurope Action Plan focus on:

- Electronic health card: to replace the paper-based health insurance card by an electronic one and support common approach to patient identifiers and electronic health records through standardisation,
- Health Information Networks: to develop health information networks between points of care (e.g. hospitals, labs, homes) with broadband connectivity,
- Online health services: to promote the high penetration and diffusion of online health services provided to the citizens.

2.4. Regulatory Activities

Major contributions to regulatory issues are being done through the research results of several R&D projects as well as special accompanying measures. In some cases, these R&D projects have significantly contributed to standards worked out at different international standardisation bodies.

Recently, the co-ordination of the activities related to the potential impact on health from the non-ionising radiation/electromagnetic fields (mobile phones) has been done by our Directorate.

3. Conclusions

The Health sector faces great challenges that need to be urgently addressed at different levels. In that respect, ICTs are critical enabling technologies that could improve access, quality and cost efficiency of health care systems.

eHealth is already a key component of the existing Health Care delivery systems and contributes to substantial productivity gains. However, more Research and Development in eHealth technologies is needed for facing the increasing demands. In particular the ambient intelligence systems for supporting disease management, prevention and well being offer numerous possibilities for cost-effective individualised health management.

The significant results of the European projects achieved in the last 10 years and the impact of them demonstrate that eHealth could be the answer to the health sector problems.
I. Introduction to User Needs, Technological Concepts and Market Trends
This page intentionally left blank
Executive Summary

This section introduces the global picture and future trends of eHealth, major issues relating to users’ needs and expectations, new concepts and technologies and business opportunities in the domain of personal computerised health management. In particular, some major issues highlighted in the workshop session and not submitted as contribution to the book are summarized below.

The healthcare reform agenda is accelerating, virtually in all developed countries, and is being powered by a series of eHealth applications which started from hospital information systems and have now extended into homecare, eNursing, ePrescribing and eBooking. The paradigm shift in the eHealth sector resulted from the following main driving forces for change:

- Mandatory search for cost containment
- Changing demographics
- Decentralisation of healthcare delivery
- Changing disease patterns
- Impact of Information and Communication Technology (ICT) including IT support for clinical decisions, telemedicine and eHealth
- More informed and demanding patients
- Well-being factor and responsibility shift into patient hand
- Knowledge management

The focus of the future health services will be more in prevention than cure and this may happen with the wide spread use of vital signs monitoring of several user groups e.g. patients with chronic disease and elderly people. Therefore, the integration of monitoring capability into smart clothing seems to be one of the most promising user friendly and affordable solutions.

eHealth is a large scale multi disciplined area which corresponds to a broad field of applications spanning from clinical applications, (e.g. teleconsultation, clinical decision support, vital signs monitoring, home telecare, ambulatory eHealth, and ePrescribing) to personalized health professional continuing education and ePrevention through longitudinal healthcare event recording and lifetime health care records. eHealth must be human centred and requirement driven.

The impact of globalisation on healthcare delivery can be seen at several levels of society. Individuals’ mobility creates new delivery paths and requirements for continuity and quality of care. To support “anywhere, anytime, always on” information access, an overall strategy for mobile access provision has to be carefully defined and regularly updated, for every users group, taking into account the locations in which the healthcare professional will be required to operate e.g. in the hospital, at home, on a patient visit (urban, rural), community centres, and GP’s practices.

The full integration of ICT into health businesses, including organizational and legal aspects, is a very long process and requires re-engineering of the whole health delivery system.

The mission statement of eHealth in the EU is to make medical services – wherever sourced – ubiquitously available across Europe, to promote eHealth & Telemedicine
across Europe at all levels, to identify barriers to eHealth & Telemedicine and use all means to overcome them, and to identify and promote eHealth technologies and solutions to achieve this aim.

Progress in science and technology offers many new possibilities and solutions that bring intelligence, speed, miniaturisation, sophistication and new materials at lower cost. The new possibilities for home care and ambulatory monitoring are provided through several technological platforms e.g. microsensors, wearable devices, smart devices and smart homes.

The current trends in healthcare and wellbeing lead to the development of a new market of personal healthcare that can be defined as “products and services to improve the health status and the personal performance outside institutional points-of-care”. Today products range from dedicated technical solutions for disease management over medical call centres to consumer offers for life critical situations, to home rehabilitation programs and fitness optimisation. The future outlook for wearable computing and Smart Fabrics and Interactive Textile (SFIT) for biophysical monitoring and position location applications is extremely strong.

However, the market of personal wearable healthcare is only at the early stage. Research and development faces several challenges such as the activity effects, the posture effects, the sensor placement effects, the baseline drift and the signal integrity. In addition, the time to market of the newly developed systems/prototypes is still long. Validation, compliance with regulations, property rights, the still high cost of technology and market opportunity assessment, slow down the commercialization process and reduce the chances for sustainable business cases. Several business models and reimbursement schemes are under consideration from manufactures and service providers, but also from national authorities and health insurances. Not to mention, of course, the education, the user acceptance, the ethical and social issues (e.g. resistance to new technologies) implied by the use of such systems.

The success of personal health and lifestyle management systems and services, possibly the next mass market after communication, will depend strongly on the positive positioning of the consumers.
New Concepts and Technologies in Home Care and Ambulatory Monitoring

A. DITTMAR, F. AXISA, G. DELHOMME, C. GEHIN
Microcapteurs et Microsystèmes Biomédicaux, INSA Lyon, Bât. Léonard de Vinci, CNRS LPM, 20 avenue Albert Einstein, 69621 Villeurbanne Cedex, France
Phone +33 (0)4 72 43 89 86, Fax + 33 (0)4 72 43 89 87, ditmar@univ-lyon1.fr

Abstract. The world is becoming more and more health conscious. Society, health policy and patients’ needs are all changing dramatically. The challenges society is currently facing are related to the increase in the aging population, changes in lifestyle, the need for healthcare cost containment and the need for improvement and monitoring of healthcare quality. The emphasis is put on prevention rather than on treatment. In addition, patients and health consumers are waiting for non-invasive or minimally-invasive diagnosis and treatment methods, for home care, short stays in hospital, enhancement of rehabilitation, information and involvement in their own treatment. Progress in science and technology offers, today, miniaturization, speed, intelligence, sophistication and new materials at lower cost. In this new landscape, microtechnologies, information technologies and telecommunications are key factors. Telemedicine has also evolved. Used initially to exchange patients’ files, radiographic data and other information between health providers, today telemedicine contributes to new trends in “hospital extension” through all-day monitoring of vital signs, professional activities, entertainment and home-based activities.

The new possibilities for home care and ambulatory monitoring are provided at 4 levels:

a) Microsensors. Microtechnologies offer the possibility of small size, but also of intelligent, active devices, working with low energy, wireless and non-invasive or minimally-invasive;

b) Wrist devices are particularly user friendly and combine sensors, circuits, supply, display and wireless transmission in a single box, very convenient for common physical activities;

c) Health smart clothes make contact with 90 % of the skin and offer many possibilities for the location of sensors. These sensors have to be thin, flexible and compatible with textiles, or made using textile technologies, such as new fibers with specific (mechanical, electrical and optical) properties;

d) Health smart homes. The aim of this method is to improve the patient’s living conditions and to avoid the cost of long hospitalization. “Exosensors” are used for measurement of the activity and behavior of the patient. The field of applications is very large, e.g. continuous monitoring of elderly populations, professional and military activities, athletes performance and condition, and people with disabilities. This new healthcare approach has to take into account lifestyle for improving prevention. For the patient to be more and more involved in his/her own therapy, new responsibilities and ethics have to be defined. A “societal health education” has to be provided to physicians and to patients to get all the benefits of this new context.
Introduction

At the beginning of this new millennium, the world is becoming more and more health conscious and health care is evolving in many ways.

The patient’s needs are evolving with the increase in information available and the new offerings of medical technology:

- Non-invasive or minimally-invasive methods for diagnosis and treatment;
- Home care, ambulatory methods, short stays in the hospital, telemedicine;
- Enhancement of rehabilitation engineering;
- Information and involvement of the patient in their treatment.

Health policy and society are changing:

- Limited health care budget and managed care;
- Improvement and control of healthcare quality;
- Prevention rather than treatment; prediction rather than response;
- Changes in society such as increase in aging population and lifestyle changes.

In the face of these changes, progress in science and technology offer, for the first time, many new possibilities and solutions, bringing miniaturization, intelligence, speed, full integration and functionality at low cost.

Figure 1. Microtechnology is a key factor for the development of biomedical wearable devices. The tree of microtechnology is growing fast and its fruit are already numerous. As the root becomes stronger through the joint effort of researchers across disciplines, the tree will continue to grow and produce new and better-tasting fruits!
In this new landscape of health and technology, microtechnologies, telecommunications and software engineering are key factors in attempts to meet the changing needs in medicine and biology and particularly in ambulatory monitoring and home care.

The basic fundamental needs (Figure 2) of human beings have existed for a long time and can be considered intrinsically “negative needs”; that is, people have sought to avoid cold, heat, hunger and thirst. Now, improvements in the standard of living have changed these needs, which are becoming more and more “positive” - citizens’ needs are now related to comfort, pleasure and, more recently, to health and quality of life. In Western society in particular, there is a fundamental shift taking place from a concentration on basic, human needs to a more positive involvement with the citizens’ quality of life and health.

Significant scientific progress in the fields of chemistry, physics, and genetics enable this development. Wearable health devices are becoming more sophisticated, and the care they provide is increasingly individualized. But do the risks counterbalance the benefits?

The future scientific direction – and policy direction in terms of health care monitoring and provision – is surely to encourage more sophisticated wearable devices, that are well and appropriately designed, simple and easy to use, but that also minimize risk.

1. The Need for Wearable devices and biomedical smart clothes [2, 13, 14, 16, 17, 29, 38, 39]

Intelligent biomedical clothes will act preliminarily as a source of patient data on his/her behavioral profile as it affects the cardiovascular risk profile, such as activity, stress, sleep and nutrition. Intelligent context-aware personalized algorithms will not only determine the situation but also provide adequate feedback for the user on how to change his/her behavior across all possible disease states.

Intelligent biomedical clothes act as a human interface for the ever increasing knowledge about health and translate this knowledge into personalized feedback for the user in any situation and with any disease status:
For healthy subjects
Interactive gaming and other self-motivational programs will help the user to enjoy a healthier lifestyle. The system will not only help the user to adopt a healthier lifestyle but will also effectively improve personal performance due to better fitness and more effective ways of coping with stress.

For citizens at risk
The system will provide adequate information on how to deal with individual risk factors and give advice on how to improve risks, like hypertension, being overweight, diabetes, physical inactivity and stress, through personalized training plans and motivation to change behavior. Early detection through long-term trend analysis will reduce the damage due to severe events dramatically. For example it will reduce the time to needle for myocardial infarction and stroke.

For post-event patients
These kinds of system can significantly improve the rehabilitation process and detect any complications at an early stage. Daily monitoring will enable new forms of personalized drug treatment and the self-administration of drug medication according to the specific behavior and circumstances of each individual.

For chronic patients
Intelligent biomedical clothes empower the user to better understand and self-manage the disease state. Early detection will limit acute events and complications that may lead to hospitalization and extended hospital treatment. The rehabilitation process will become a lifelong process in which patients and family are also actively involved.

The use of intelligent biomedical clothes will not only improve the situation for the user but will also enable medical professionals to react timely and specifically to the disease of an individual through significantly improved timely diagnosis and new forms of therapy and personalized treatment. It will help to improve the effectiveness of the healthcare system through cost-efficient access to the best care and it will empower each individual to have a longer and healthier life with increased personal performance. Intelligent biomedical clothes and wearable devices can act as a key enabler for a lifelong continuous health improvement process for all individuals.

The vision of continuity of care, integrating prevention, lifestyle and treatment of disease, was also adopted in ancient Greece. Asclepios, the father of medicine, was also the father of two daughters: Panakea, whose pitcher contained a universal drug for the treatment of all disease, and Hugieinon, who wore fruits, olive oil and vegetables for quality of life and prevention of disease (Figure 3).

Until recently, a problem with medicine was that it was almost completely oriented towards treatment using molecules, drugs, mechanics, prosthesis and surgery. More recently, advances have been oriented in a complementary fashion, toward dietetics, quality of life, hygiene, early detection of diseases and continuous monitoring. The concept of ambient intelligence is at last applied for health.

Non-invasive measurements on humans are particularly suitable for several reasons (Figure 4). They are painless, they preserve the capability of the skin to protect against infection, they allow easy access to the medical devices and they are user-friendly.

The flip side of these large advantages is usually a high complexity in principle and design of the devices. It is clear that it is difficult to measure deep phenomena from
the surface of the skin. The measurement principles are indirect and necessarily more complicated. There are dozens of non-invasive measurements on the human body but less than ten basic parameters are currently measured and recorded with ambulatory methods. The choice of placement of non-invasive devices (Figure 5) has to satisfy several criteria and limitations, e.g. obtaining the best signal/noise ratio, the best fixing and the best ergonomics, while also remaining unobtrusive and painless. Several solutions are available:

- Independent sensors and devices (used in laboratories);
- Perimetric fixing using the body segments and the circular body part (e.g. head, neck, trunk, arm, wrist, leg and ankle);
• Hat, belt, bracelets, socks, shoes, headband, smart clothes.

Of these possibilities, smart clothes, belts and wrist devices are frequently used.

2. Wrist-Wearable Medical Devices

One of the best places to wear an ambulatory device is the wrist. The wrist is a very common place to wear a watch or other devices and nowadays most of the ambulatory devices for sport are worn on the wrist [24].

Wrist devices are readily accepted by anybody. Moreover, as the skin of the hand has the greatest density of sensors and actuators of the body, the wrist and the hand represent a privileged place for physiological measurement, including skin temperature, skin electrical conductance and potential, actimetry, blood oximetry and heart rate. However, wrist devices also have constraints:

• They have to be light and small, in order to not disturb the user. This implies sophisticated power management, wireless data transmission and enhanced miniaturization.
• Sensors have specific locations and wrist devices should be designed according to them.
• They have to be user-friendly and safe. This implies intelligent ergonomics.

Progress in informatics, signal processing, microelectronics, battery technology, and telecommunications is the key to opening up all the possibilities of wrist devices, through enhancing autonomy, low weight, user-friendly interaction and wireless networking.

The wrist has been used for a long time to wear watches, bracelets, jewels etc. because fixing something on the wrist is easy and the mobility of the wrist allows for good ergonomics and easy reading. Three examples of specific uses and a corresponding device are actimetry (“Vivago”), vital signs (“Amon”) and sensorial reactivity and vigilance (“Marsian”).

2.1. Vivago WristCare [34]

The Vivago WristCare (Figure 6) is a device that automatically monitors a person’s well-being 24 hours a day (Figure 7) and transmits automatically to a station called a Multi-
Link within a maximum range of 20 meters. The Vivago wrist device has about 6 months of battery life, but the battery should be replaced by a specialist. During the first four days of use, the unit adapts to the user’s normal activity level by measuring micro and macro movement, skin temperature and skin conductivity. If the Vivago WristCare registers a significant change in the user’s activity level, it automatically sends an alarm to the alarm recipient.

The Vivago WristCare is able to detect hypothermia, activity of the patient and whether the WristCare is being worn or not. Those three parameters can determine if the situation of the patient is normal and, if they are not, trigger an alarm. The Vivago WristCare can also determine the location of the patient in an institution in order to provide access control or to check if the patient has exited a door or not. This last feature has been designed particularly for users with dementia or mental health problems.

In addition to the wrist unit, the Vivago home system includes a base unit that is connected to the telephone network and an electrical outlet. The base unit wirelessly receives the data from the wrist unit and transmits alarms and notifications to the alarm recipient. The alarm can be routed to any telephone and enable a conversation through the base station. The Vivago system offers benefits beyond the traditional push-button alarm. If desired, the wrist unit can transmit notifications when it is removed or reattached.

This ensures that the unit is in use and that the user is supported by the unit’s security features. The wrist unit continuously monitors its own operation, providing notifications on low batteries and connection problems. The wrist unit can trigger an alarm when the

**Figure 6.** The Vivago WristCare System.

**Figure 7a.** Vivago’s activity record for a normal aged person. During the day activity is high and during the night the activity is very low. This patient sleeps well.

**Figure 7b.** Vivago’s activity record for an aged person with low-level activity. Activity day and night is low and there is almost no difference between the two.
user is unable to do so. Such a situation could be the immobility resulting from a bad fall or loss of consciousness. All of the above functions can be switched on or off by remote programming depending on care needs and the user’s health.

2.2. Advanced care alert portable telemedical MONitor (AMON) [30]

AMON is a terminated European-Commission-funded project which performed research, development and validation for an advanced wrist personal health system. The system is designed to monitor and to evaluate human vital signs using advanced biosensors (Figure 8). The Wrist Monitoring Device (WMD), the wearable component of AMON, gathers vital information from the sensors, analyzing it using a built-in expert system. The WMD transmits the data to a remote telemedicine centre, for further analysis and emergency care, using GSM or GPRS cellular infrastructure. The device includes sensors for key parameters such as heart rate, heart rhythm, 1-lead ECG, blood pressure, O2 blood saturation and skin temperature. Future optional sensors could include 12 lead ECG, EEG, a non-invasive glucose meter and respiratory peak flow sensors.

AMON will enable European patients, who are not confined to a hospital, to monitor and continuously analyze their vital signs. This will help them to participate actively in their on-going care. AMON will provide monitoring of health status at the point and time of need, which will give patients freedom of movement and will enhance their quality of life. AMON will ensure continuity of patient care by providing continuous medical monitoring.

The main benefit is that the European user will be able to have medical monitoring or an emergency alert any time of the day, while having a normal life at home, at work and at leisure places.

2.3. MARSIAN: Modular Autonomous Recorder System for measurement of Autonomic Nervous system activity

The autonomic nervous system activities (non-conscious) in real and ambulatory conditions are related to emotional, sensorial and cognitive responses and activities [12].

MARSIAN (Figure 9) is a hybrid device associating the advantages and the specificity of smart clothes and of wrist devices. Research is now focusing on smart clothing solutions to enhance the use and the reliability of sensors [10]. The MARSIAN smart
MARSIAN Project

Figure 9. MARSIAN, Modular Autonomous Recorder System for measurement of Autonomic Nervous system activity, is an ambulatory micro central composed of smart clothing and gloves and a wrist device.

glove has a specific design to ensure both a good contact from skin to electrodes whatever the hand’s motion and a correct furtivity of the glove so as not to modify the typical physiology of the hand’s skin.

The MARSIAN wrist device ensures real-time physiological data acquisition, treatment and wireless transmission in a minimum size. Remote software displays and stores data and provides a semi-automatic analysis in order to facilitate the expert’s conclusions. This wrist device has 6 hours autonomy at full utilization.

Experimentation with MARSIAN has been already done. The results have the same quality as a laboratory standard device already developed and tested by A. Dittmar and G. Delhomme (CNRS LPM, INSA Lyon, France) [7,22]. The ergonomics of the software has also been enhanced to enable user-friendly applications and experiments.

The non-invasive multiparametric measurements carried out by MARSIAN have a large field of applications and research uses [4,6,23]. Main research topics are:

- Vigilance level and task-related response (cognitive and physical),
- Response to odor, taste, touch, vision (e.g. shape and color), sound (e.g. speech),
- Research on thermal and environmental comfort responses and states,
- Comparison with conscious and verbal indications,
- Study in real conditions of action programming in sport,
- Mental imagery training and study for sport,
- Study of behavior and stress.

Moreover, in order to get an index or a decision tree to determine ANS responses to thermal comfort, research is also focused on subject responses in comfortable and uncomfortable levels of various environmental factors, such as temperature, humidity and air velocity.

MARSIAN is fitted both to analyze instantaneous emotional responses which occur almost immediately after the stimulation (for example after odor stimulation) and to analyze longer responses which characterize a state change (for example, thermal comfort or discomfort). Figures 10 and 11 show two types of analysis [1].
Figure 10. ANS parameter variations for ventilation stimulation. Skin temperature decreases and respiration increases. Skin blood flow also shows vasoconstriction. ANS parameters should be analyzed with a 10 minute time scale for thermal comfort analysis.

Figure 11. ANS parameter variations for odor stimulation. SP and SC (here shown as skin resistance) modification are particularly visible. Just after stimulation SC increases (resistance decreases) as SP. Thermovascular parameters also show typical reactions. ANS parameters should be analyzed with a time scale of less than 1 minute for emotional responses.

3. Ambulatory Devices

3.1. Enhanced Personal, Intelligent and Mobile system for Early Detection and Interpretation of Cardiological Syndromes (EPI-MEDICS) [31]

In Western countries heart disease is the main cause of early disability and premature death. Moreover, because of the ageing of the population, the number of cardiac deaths is steadily increasing, and almost two thirds of them occur before arriving at the hospital.