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Integrated IT environment for people with disabilities: a new concept

Research Article

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Abstract: This article evaluates the authors' own concept of integrated IT environments for people with disabilities. Increasing numbers of disabled people and elderly people are affected by shortages of medical specialists and limited funding for medical care. Integrated IT environments for people with disabilities – through integration of various technical and medical solutions into one flexible system – are one way to provide increased independence and improved quality of life for disabled, elderly and severely ill people. The aim of this paper is to assess the extent to which the available possibilities in this area are being utilized, including the authors' own concept. The implications of technological developments are discussed to lay the groundwork for further research.

Keywords: *Long-term rehabilitation • Disabled people • Elderly people • Integrated solutions*

1. Introduction

Increasing numbers of disabled people and elderly people are affected by shortages of medical specialists and limited funding for medical care. This alarming situation is due to continued progress within medical science and technology, which means there are increasing numbers of surviving newborns and premature babies, post-stroke patients, post-accident patients and so on. At the same time, this progress does not guarantee the patients' return to full health, but only the best possible functional status. It is also important to bear in mind that increased social awareness and the biopsychosocial model of holistic health care call for improved quality of life and increased independence for people with disabilities. This situation requires urgent solutions, and integrated environments for disabled people are one of them.

The aim of this paper is to assess the extent to which the available possibilities in this area are being utilized, including the authors' own concept.

2. Integrated IT environments for people with disabilities: the current status

Integrated environments for disabled people are widely regarded as the next step forward in assistive technology. The integration of various technical and medical solutions into one flexible system may have several important advantages. The first of them is an adaptive complex solution and compatibility with the principles of the assistive technology (AT) [1]. Where possible and beneficial, compatibility with the principles of universal design [1,2] and Human Factors Engineering (HFE) methods [3] is a second advantage may be considered. The third of them would be considered easy adaptability to the type and severity of deficits, since different user interfaces may be used separately for people with motor impairments (including control systems for intelligent wheelchairs and exoskeletons), very severe impair-

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ments of the central nervous system (CNS) – including brain-computer interfaces and neuroprostheses, and sensory (including vision, hearing, cognitive, etc., and even multiple) impairments. Other advantages may be: improved quality of life and increased independence for disabled users, in most cases without the need for additional assistance from other people, easy adaptability to the eclectic approach in rehabilitation [4], interoperability among the assistive devices used, increased flexibility thanks to the ability to switch from one device/subsystem to another, adding new ones as required (e.g. due to changes in the user's health status), and increased effectiveness through synergy. A significant influence on further development may show increased mobility for selected functions (in some cases), lower costs, thanks to the sharing of media and infrastructure, and the possibility of using commercial off-the-shelf devices where available.

A few articles investigating the issue of integrated systems for disabled people have been published, most of them more than five years ago. The concept of assistive device integration was raised by Nisbet as an alternative to mounting assistive devices on a powered wheelchair, which was assessed as time-consuming, expensive, and resulting in compromised performance [5]. A review of the research concerning communication and control, internet access and wheelchair guidance systems was presented by Ding et al., providing a look at the status of electronic assistive devices in 2003 [6]. Unfortunately, the rapid pace of technological developments in the meantime has limited the current value of these analyses.

Health care professionals and engineers can certainly play a significant role in facilitating patients' access to integrated systems and related services, and to strategies that enable them to participate in community life. Important factors in this include the patient's physical independence (defined as the physical and/or cognitive ability to fulfill tasks), and self-care management (defined as access to and the ability to use and control devices/resources supporting living in the community regardless of the patient's level of physical ability) [7]. Recent reports have shown that emerging technologies (technical innovations) may significantly and positively influence disabled people's quality of life [8-11].

3. A novel solution

According to the approach proposed by Vanderheiden [1], the best solution is a combination of two main approaches: 1) the use of assistive technologies where necessary (or where those technologies provide sufficient additional advantages to the patient/user), 2) where possible and commercially practical, the use of universal design [1]. The user/patient's main expectation is to function independently [7], so the final decision may depend on practicality. Moreover, it needs to be kept in mind that disabled people who use a technology to do an activity may receive lower scores on functional assessments [7]. The authors' own proposed solution is shown in Figure 1. An open-to-development environment consists of eight groups of solutions used according to the needs of the patient. The current configuration of solutions may be changed and/or developed into another configuration depending on changes in a patient's health status, treatment needs, etc. For example: patients with severe CUN deficits in the early stages of therapy/rehabilitation may only need to use BCI for diagnosis, communication and control (bed control, bedside robot control) purposes. This same patient during long-term rehabilitation may use i-wear solutions for diagnosis and communication, and BCI for wheelchair or exoskeleton control. Particular elements of the aforementioned environment have been described in our previous publications [12-15].

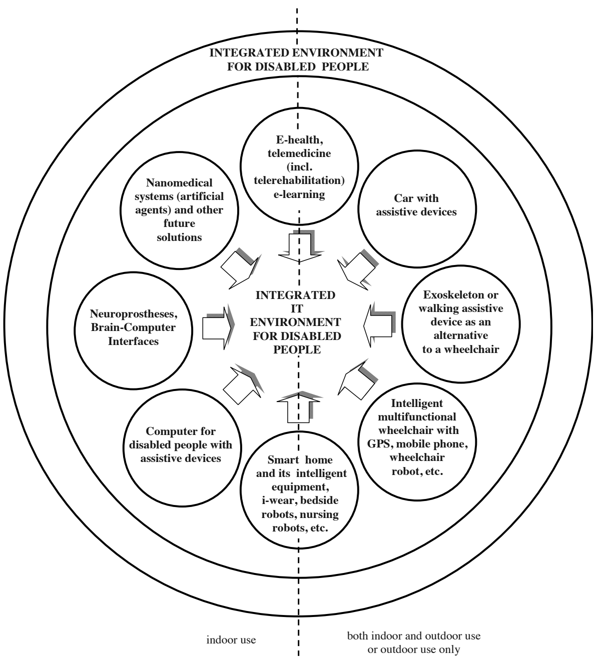

Figure 1. The concept of an integrated IT environment for disabled people [12-15].

There are at least several main assumptions. The first of them is the use of commercial off-the-shelf (COTS) devices and up-to-date research on smart home and i-wear. Thanks to i-wear technology and measurements of the user's bio-electrical parameters, as a basic solution, the user can serve as a mobile system interface for layers 4-7 of the ISO-OSI model (International Organization for Standardization – Open Systems Interconnection Reference Model – ISO/IEC 7498-1; layers 4-7 constitute function of each users's terminal). This way changes in the user's position result in corresponding changes in his/her access to information and resources, allowing him/her to make informed decisions (e.g. for geolocalisation, access to telemedical data, alerts, etc.). Other user interfaces may be used in accordance with individual needs. The use of i-wear (or similar) technology provides access to services at home as well as guaranteeing the user's mobility; there is a need for user-tailored network adaptation (layers 1-3 of the ISO-OSI model – they constitute a communication network between network terminals, e.g. wireless computer network, or mobile phone network, etc.).

The concept of the user as a key part of the system interface is shown in Figure 2. The user and its features (from biophysiological signals to activity) are regarded as the kernel of whole interface. Only the identification of the selected user's features and the associated authentication may activate the interface and whole system. I-wear technology and an integrated environment provide another shell for him/her, allowing for access to more advanced functions and resources. This way a user-centered human-machine interface may become something natural in systems designed for disabled people, significantly enhancing their abilities. Human-machine interaction that is as natural as possible may be a key issue for children with disabilities or adults who temporarily use such systems – in this way abandoning "artificial" support may be easier for them (when possible thanks to recovery due to progress in medical sciences or bioengineering).

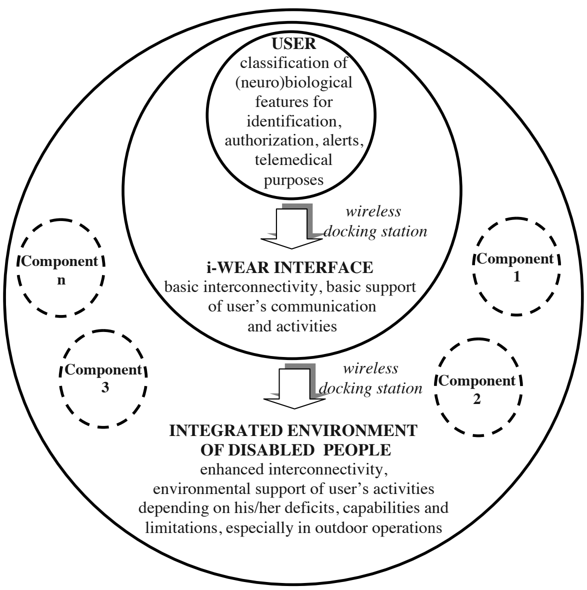

Figure 2. The concept of the user as the key part of the system interface.

The flexibility of the system facilitates common goal setting and patient-oriented therapy, e.g. participation in activities identified as highly meaningful and important to the user/patient. More detailed results, especially in the area of communication and control systems, will be presented in future papers. All the aforementioned advantages make this system a very promising solution for disabled people. The solution can also be adapted for elderly people or for severely ill users (as a temporary solution during recovery). The perceived disadvantages of the proposed solution are: the dehumanisation of health care and social care (including a phenomenon similar to the virtual reality trap), issues related to brain enhancement and human identification (see Professor Kevin Warwick's research [16]), questions regarding the safety of the proposed solutions, neuroethics and neurosecurity. Although manufacturers will see that increasing numbers of disabled, elderly and/or severely ill people may constitute a very important group of customers, the increased technology gap between the rich and the poor (and between developed countries and underdeveloped countries) can be a serious problem. Another problem concerns children and some elderly people using the systems described – they will still need caregivers, even if supported by intelligent environments.

The main factors limiting the use of the solution described are: the need for changes in social awareness (especially in developing countries promoting a better understanding of disabled people's needs), the attitudes of certain social, cultural and religious communities toward the use (or nonuse) of the technologies involved, and the long-term influence on community life and decisions regarding the user's participation in it [7]. In addition, there is a need for organisational and procedural changes within current health care and social care systems, the impossibility of using the described system in certain cases, such as complete locked in syndrome (CLIS), where even brain-computer interfaces are currently impossible [17], and a lack of user-friendly mobile interfaces adapted to the disabled people's needs. Current solutions in this area based on smart home technology are not mobile, and more i-wear solutions are needed, based on mobile phones (smart phones), mobile internet access or satcom. Considering there is a lack of common standards and recommendations (usually each manufacturer develops their own solutions, although most of them are based on a 7-layer ISO/OSI model), a lack of open-source solutions that would be easy to use and to share, the huge cost for the user during the first years of use, the lack of infrastructure, the fact that funding is based mainly on governmental and social initiatives rather than being commercially driven, current initiatives for disabled people seem be isolated projects rather than large-scale undertakings.

4. Possibilities for adaptation and interconnection

An efficient user interface is only one part of the solution for the purposes of an integrated environment. Another aspect is interoperability within contemporary and future systems. Compatibility with external systems, such as the Hospital Information System, may be key to telemedical and telerehabilitation services (including alerts). Moreover, support for external systems like mobile phone systems, satcom and GPS may be essential due to the increased mobility of the patient/user. ISO-OSI compatibility may be considered as crucial. Possible interactions between the proposed integrated IT environment for disabled people and associated systems (including hospital information systems – HISs) are presented in Figure 3. This interoperability and cooperation allow not only for medical data sharing (e.g. data sets from exoskeletons as useful information for telemedical systems) within the whole system, but also provide wider effectivity and synergy of the system elements (use of BCI for early diagnosis, communication, and control of devices, e.g. bedside robot, i-wear, smart home, wheelchair or exoskeleton). Thus novel clinical protocols may be needed to fully utilize all abilities of such a system. Huge and complex data sets may be another source of information for expert systems thanks to computational intelligence (e.g. data mining systems).

The concept of an integrated IT environment for disabled people may play a key role in currently developing concepts in contemporary medicine, such as patient tailored therapy, also called personalized medicine (in oncology, cardiology and other fields). Thus it is important to provide detailed research in accordance with the Evidence Based Medicine paradigm as well as clinical guidelines and recommendations describing indications and contraindications. Simultaneously, it needs to be borne in mind that the solution described is only a supportive part of a contemporary health care system and social system. The advantages of integrated environments may be important in long-term therapy, but "conventional" solutions will still be the most important in interventions in the acute stages of the therapy. On the other hand, neurological rehabilitation and its specific intervention techniques (NeuroDevelopmental Treatment Bobath, proprioceptive neuromuscular facilitation, etc.) will still be based on the experience of the physiotherapists. Due to the high standards of knowledge and the experience of its adherents, it seems that the emerging eclectic approach will provide the highest level of therapy [4].

5. Directions for further research

The main direction for further research is not new: Ambient Intelligence (AmI) systems and Affective Computing (AC) systems based on the Internet of Things (IoT). It requires a huge technological leap beyond current limitations towards intelligent multimodal interfaces.

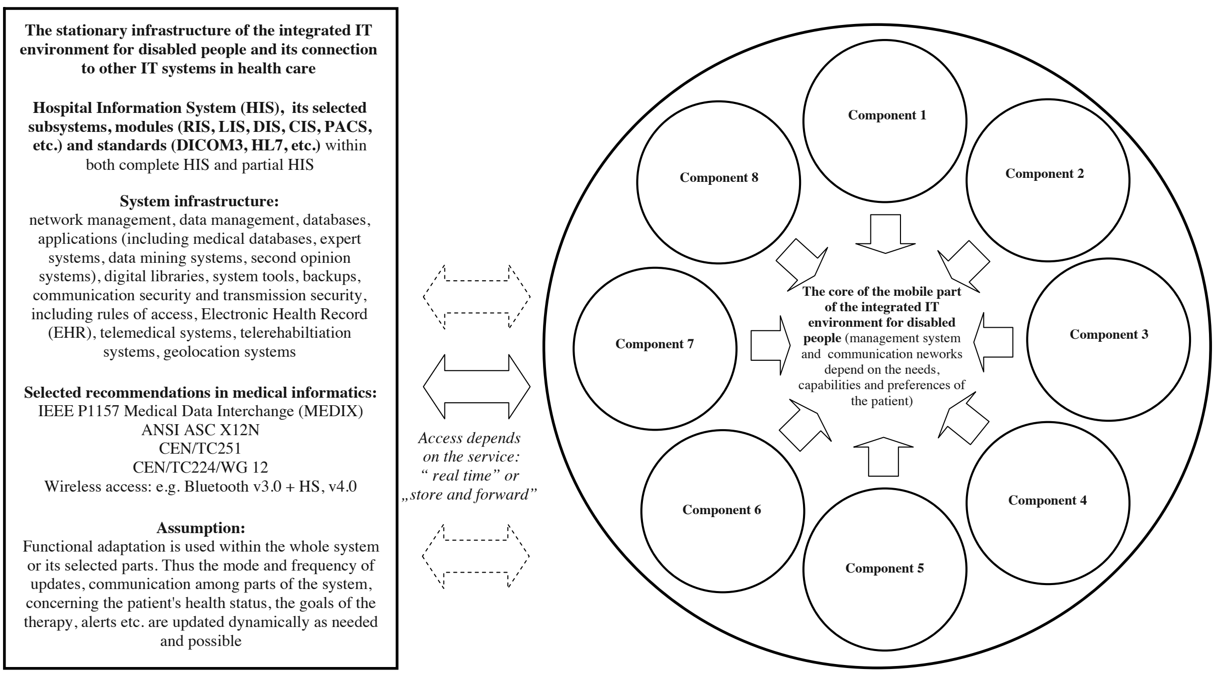

Figure 3. The concept of interaction in the integrated IT environment for disabled people [18].

Advances in wireless communication, voice controlled computers and devices and multiomodal interfaces will be very useful in this field. Disabled people's various needs depend on the type and severity of their disorders, and the same products (or functions) may need to be offered in various formats, so that the individual user can choose the appropriate form for him/herself. This may require a new approach in artificial intelligence systems.

Integrating solutions for purposes like (e.g.) telemedicine and telerehabilitation systems may be a very important part of future health care and social care systems. A whole new model of health care may need to be defined in order to exploit the new possibilities.

Current technological development is very rapid. Novel solutions, like brain-computer interfaces, electrochemical neurprostheses [19,20], biomedical microelectromechanical systems (bioMEMS), biomedical nanoelectromechanical systems (bioNEMS), lab-on-a-chip (LOC) technology, exoskeletons, and intelligent robotic wheelchairs may soon be replaced by newer ones. This means that current and future solutions should be as open to development and interconnections as possible. As an example: Based on the number of publications about the subject, the authors estimate that approximately 60% of current BCI solutions are based on electroencephalography (EEG), both implanted and recorded through the scalp. But it seems that Superconducting Quantum Interference Device – MagnetoEncephaloGraphy (SQUID-MEG) solutions are the most promising technology in this area, due to the fact that they are wireless. Unfortunately, the current cost and technical problems associated with portable SQUID-MEG solutions make their use difficult at best [21,22].

6. Discussion

Systems like the solution described above may give new meaning to the word "disability", and thus should be the subject of governmental and social initiatives and support. Particular attention should be given to current and future governmental and social policies, which should emphasize equal opportunities for all citizens, including those who are disabled, elderly and/or severely ill. This process seems be to slow and difficult compared with the rapid pace of technological developments.

In addition to the development of the solutions described, there are other issues to consider, including that the Human Activity Assistive Technology (HAAT) model [23] and other similar models need enhancement, any useful solution needs to be compatible with the recommendations of ISO26000, the principles of Assistive Technology Service Method (ATSM), Assistive Technology Device Classification (ATDC) and Matching Person and Technology (MPT) as an "evidence-based, user-centric, interdisciplinary method to improve individual and organizational performance for rehabilitation (including assistive technology) services" [24]. There is a need for new, more IT supported diagnostic tools for device selection, and a need to prepare both medical staff and technical specialists (e.g. biomedical engineers and/or rehabilitation engineers). Moreover, there is a need for a new help desk and troubleshooting system, available worldwide if possible.

7. Conclusions

A simple basic physical deficit may lead to huge problems in daily life. A person's independence may be limited by dysfunctions on various levels and influenced by numerous factors. It seems that only adaptive complex environments based on novel IT technologies may improve the situation of disabled people. Integrated solutions hold a great deal of potential as a new model of assistive technology for disabled people, especially in developed countries.

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