Advances in Building BodyInNumbers Exercise and Wellness Health Strategy Framework

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Abstract: Smoking, excessive drinking, overeating and physical inactivity are well-established risk factors decreasing human physical performance and increasing incidence of chronic diseases. Moreover, epidemiological work has identified modifiable lifestyle factors, such as poor diet, physical and cognitive inactivity that are associated with the risk of reduced cognitive performance. Chronic diseases present an enormous burden to society by increasing medical costs and human suffering. Exercise and wellness health strategy frameworks aiming at influencing modifiable lifestyle risk factors in voluntarily enrolled individuals and thus decreasing incidence of chronic diseases are then very beneficial. However, such frameworks also need a supporting software infrastructure. The advances in building of such software infrastructure, the BodyInNumbers software system for rapid collection and analysis of health related data, are presented in this paper. They include the changes in the system architecture, redefinition of user roles related to data and metadata security and design, implementation and integration of new modules for collection and management of electroencephalographic/P300 event-related potential data and new modules for collection and management of data from measurements of physical strength and balance. The results of the system testing are finally described.

1 INTRODUCTION

Chronic diseases present an enormous burden to society by increasing medical costs and human suffering. Recent data estimate that physical inactivity and poor diet caused 40,000 deaths in 2000 (Ellison et al., 2016), ranking second only to tobacco. Numerous studies link cardiovascular disease risk with the high glycaemic index/load of carbohydrate-based diets (Grasgruber et al., 2016). Approximately one tenth of the world population suffer from obesity and prevalence of obesity among children and adults has doubled in 73 countries since 1980 (Afshin et al., 2017). Physical activity and a balanced diet are effective interventions as an essential weapon in the war on chronic disease. Clearly, there is overwhelming evidence linking most chronic diseases seen in the world today to physical inactivity and inappropriate diet consumption.

Over the past decades, considerable knowledge has accumulated concerning the significance of exercise in the treatment of a number of diseases, including diseases that do not primarily manifest as disorders of the locomotive apparatus. Today, exercise is indicated in the treatment of a large number of medical disorders. In the medical world, it is traditional to prescribe the evidence-based treatment known to be the most effective and entailing the fewest side effects or risks. The evidence suggests that in the selected case exercise therapy is just as effective as medical treatment and in special situations more effective or adds to the effect. In this context, exercise therapy does not represent a paradigm change it is rather that the accumulated knowledge is now so extensive that it has to be implemented.

Data also suggest that aerobic exercise is associated with a reduced risk of cognitive impairment and dementia; it may slow dementing illness. A compelling argument can be made for this via two plausible biologic pathways. First, a convergence of evi-

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dence from both animal and human studies suggests that aerobic exercise may attenuate progression of neurodegenerative processes and age-related loss of synapses and neuropil. This may occur via a direct influence on neurodegenerative disease mechanisms or facilitation of neuroprotective neurotrophic factors and neuroplasticity. Not to be overlooked, however, is a second pathway, cerebrovascular disease. Cerebrovascular burden contributes to dementia risk, especially via small vessel disease (e.g. lacunes and leukoaraiosis). Vascular risk factors are well known to be reduced by aerobic exercise. Thus, ongoing, moderate-intensity physical exercise should be considered as a prescription for lowering cognitive risks and slowing cognitive decline across the age spectrum (Matura et al., 2017).

Numerous noncognitive, nonvascular benefits additionally benefit from exercise, which may be especially relevant to aging population. This includes reduction of osteoporosis and fracture risk (Rizzoli et al., 2009) age-related sarcopenia (Thomas, 2010) and benefits directed at depression (Thomas, 2010) and anxiety (Conn, 2010). An exercise program may improve behavioral management in seniors with dementia (Dunn, 2010) and fall risk (Teri et al., 2003). Importantly, long-term physical activity and fitness reduce mortality risk in the general population. (Kokkinos et al., 2011; Allan et al., 2009).

Mounting evidence shows regular exercise helps reduce levels of brain loss and helps our cognitive abilities as we age. A Florida study demonstrated that exercise at midlife may reduce the odds of dementia in older adults by up to 60 percent (Lee et al., 2010). Such extraordinary findings were corroborated by several other studies, including University of Lisbon study that found that physical activity benefits happen independently of age, education, vascular history or diabetes (Andel et al., 2008).

To address modifiable lifestyle health risk factors, many different wellness intervention projects around the world have been introduced. This paper presents a progress report of such a wellness project that is currently conducted at the Department of Computer Science and Engineering, University of West Bohemia in the Czech Republic, and is called BodyInNumbers (Bruha et al., 2017).

Its focus is on definition and automation of the data collection process in order to capture a huge amount of heterogeneous health related data from many users in various environment in a short time. The architecture of an underlying application has been extended and changes in the architectural design related to the management of user roles and related data and metadata security have been made. A new module for collection and management of electroencephalographic/P300 event-related potential data and new modules for collection and management of data from measurements of physical strength and balance have been designed, implemented and integrated into the system. A questionnaire given to participants has been digitized. Finally, the related mobile application for rapid collection of health data has been improved.

The paper is organized in the following way. The next section shortly deals with the state of the art in the field of publicly available health related applications that focus on cognitive and/or physical health of its users. Section 3 takes a closer look on the architecture of the BodyInNumbers software system and especially deals with the definition of user roles related to the data and metadata security issues. The 3.2 section brings changes in the system implementation. The last section summarizes the parts of the system that have been already implemented and introduces the future steps.

2 STATE OF THE ART

The effects of a healthy lifestyle on physical and cognitive functions are of interest not only to researchers or physicians, but also to people who feel their own responsibility for their health. Then a well designed, user friendly and secure exercise and wellness system containing a large collection of annotated human health related data could be suitable for further analysis of lifestyle influence on human cognitive and physical performance. The acquisition of human health related data must be also efficient and flexible, both in non-lab and lab conditions. Only a sufficient set of data and metadata (e.g. age, gender and summary of the participant's current life style and health) allows researchers to perform further analysis, e.g. to detect early symptoms of starting chronic diseases.

There are many applications that allow collection of health related data, e.g. the Apple Health App or Google Fit are their well known representatives. Another prime example is Vitabot that specializes in nutrition programs and goal tracking, with the ability to connect personal fitness trainers with users, widely used in the fitness industry (Vitabot.com, 2017). Indares.com (Chmelík et al., 2017) has been developed with the aim to support education and research in the field of physical activity. A variety of games is usually used for cognitive training, e.g. the Lumino City puzzle game (State of Play games, 2014) or My Happy Neuron (HAPPYneuron, 2017). There are also projects utilizing reaction time as a physiological measure (e.g. (Harris et al., 2010; Bolandzadeh et al., 2015; Fenesi et al., 2016)).

In contrast to these systems and applications, our BodyInNumbers software system is able to collect and manage two very different data and metadata groups - heterogeneous health related data (including reaction times) and electroencephalographic (EEG) /event-related potential data (ERP) recordings. To the authors best knowledge, there are no systems publicly available that would contain such various data: reaction time data, P300 event-related component data and other supportive health-related data (color vision, spirometry, electrocardiography, blood pressure, blood glucose, body proportions and flexibility) together with corresponding metadata (except others, for example, a summary of the participant's current lifestyle and health).

The set of supportive health-related data was selected from two points of view: it has to represent a basic characteristics of human physical performance and the data have to be easily collected also in non-lab conditions.

3 BODY IN NUMBERS SOFTWARE SYSTEM

3.1 Architecture and Design

The architecture of the BodyInNumbers software system is shown in Figure 1. The system design fully follows the strict legislative requirements for storing and managing personal and sensitive data and metadata. The architecture of the system is thus designed to fit these needs and includes pseudonymization, anonymization and encryption of all sensitive and personal information stored or processed within the system. A set of user roles is defined to access the system functionalities and the data and metadata stored in the system.

The system itself is divided into five essential components: kernel, data warehouse, remote logger, API, and web interface.

3.1.1 User roles

On the basis of activities that a user can perform within the BodyInNumbers software system and on the basis of privileges when accessing the data and metadata stored in the system the following user groups have been proposed:

- Data acquisition group – people who are permitted to set a data recording procedure/collect data/manage and verify collected data.
  - coordinator – a person responsible for the definition of a data collection procedure, he/she can determine the data collection procedure within the application,
  - leading experimenter – a person responsible for the correct conduction of a specific measurement and for the quality of resulting data and metadata, he/she can view measured data and edit them in the application,
  - experimenter – a person responsible for the measurement itself, he/she can insert new data into the application.
- Control authority group – executives have access to the data stored in the system.
  - ethics committee – can view a list of experiments and measured data in anonymous and pseudonymous form,
  - top management of the corresponding departments, faculties and research centers – can view anonymous and pseudonymous measured data.
- Research group – people who work with measured data. They have access to any data according to their permissions.
  - data analyst – can view and export any data in the anonymous form,
  - nutritional counselor – can view any measured person in the anonymous and pseudonymous form,
  - physiotherapist – can view any measured person in the anonymous and pseudonymous form,
  - cognitive trainer – can view any measured person in the anonymous and pseudonymous form.
- Technical support group – people who can view all data and have full access to the application.
  - data manager – person with full permission to view, edit and delete measured data. He/she is the only person who can access personal data and metadata via the web interface,
  - security administrator – person with an access inside server for configuration,
  - system operator – owner of the system.
- Participants group – people who participated in the measurement can access only their data and metadata.

3.1.2 Kernel

Kernel is the most vital and secured component of the system. It is accessible only within a private network and direct access is granted to a very limited number of users and services. The main responsibility

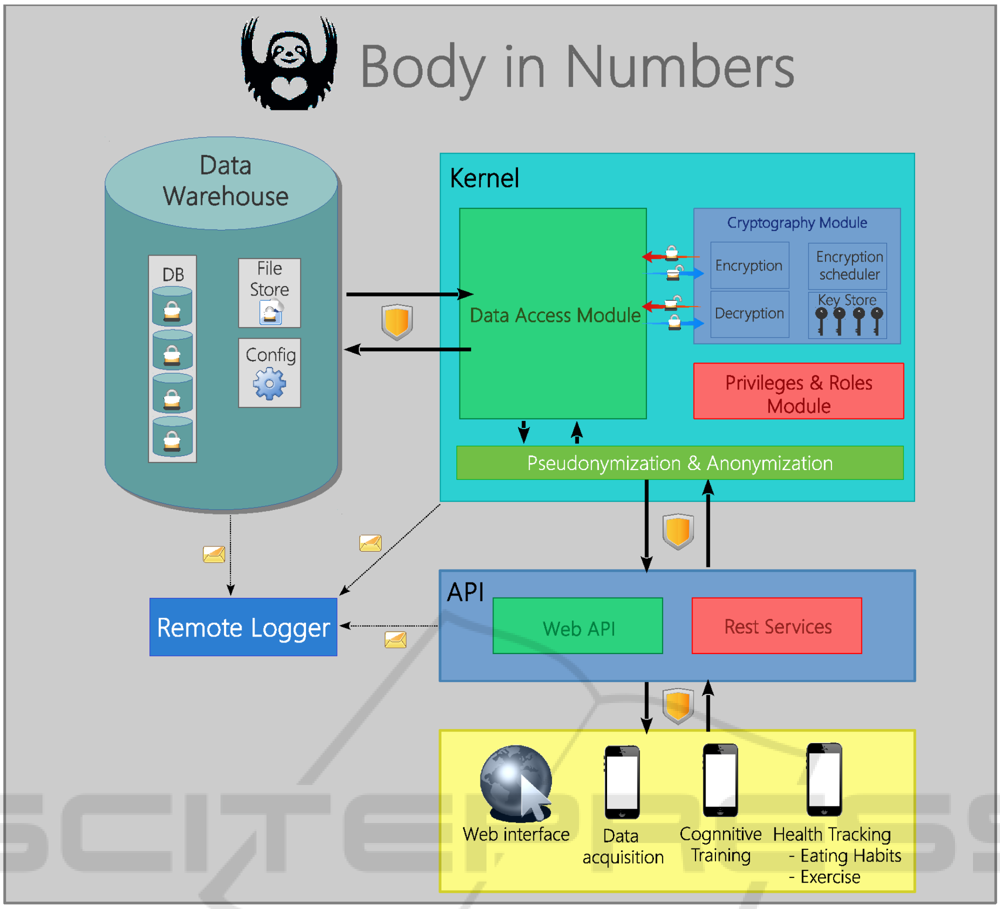

Figure 1: Software prototype architecture.

of the kernel is encryption and decryption of health related data based on asymmetric cryptography and anonymization of all personal data when these are transferred out of the kernel.

Health related data processed inside the kernel are divided into several groups (based on their content, sensitivity, etc.). Each data group has its unique pair of keys, one key for data encryption and the second one for data decryption. The keys are associated with the presented user roles and privileges within the BodyInNumbers system.

For example, John who is a diabetes data analyst has a privilege to read measured data inside the diabetes data group only, this privilege is associated with the single decryption key of this data group. Jane as a member of the data acquisition group has privileges associated only with the encryption keys, i.e. she is able to encrypt and send measured data but cannot read them (or any other data) after their encryption. Moreover, the user does not bear any knowledge about cryptography procedures running in the background.

Decryption is handled only by the kernel, while encryption may be delegated to the client side in some cases to decrease the server load. The data processed and encrypted inside the kernel are persistently stored in the data warehouse.

3.1.3 Data Warehouse

The collection of personal data and design and implementation of their storage are managed according to law. The data warehouse component consists of several database servers running on separate machines. It ensures data replication to prevent possible data loss and suitable data distribution, i.e., for example that the subject's informed consent containing subjects name and contact is not stored on the same physical machine as subjects measured data to prevent any possible personal information leakage.

3.1.4 API

The application programming interface (API) is a component which serves as a gateway to the BodyInNumbers system. Communication with API is ensured by using a secured channel (https, authentication tokens,...). The request or measured data are passed to the kernel when authentication and authorization is finished.

3.1.5 Web Interface

The web interface component (the bottom part of Figure 1) enables users to visualize, edit, insert and export health related data. It is also provides necessary functionality for data acquisition group (scheduling of measuring sessions, planning of technical and human resources etc.) and basic statistical and analytical functionality. All requests of this component are handled by the REST based API.

3.2 Implementation and Deployment

3.2.1 Kernel and API

The design takes into account the appropriate storage and backup of health related data. The disadvantage is that every operation over the data is expensive (delegation of requests, multiple encryption). For this reason, the optimized source code of server-side components will be re-implemented in C++.

3.2.2 Web Interface

The web interface is based on the Flask micro python framework and MVC pattern. All functionality is structured into separated modules covering specific parts of the system. The functions of modules are tied to the kernel of the system. Every operation which requires data must request the system kernel for them. Rest API is defined for collecting data from client devices.

- The General module covers functionalities affordable also for non-logged users.
- The Admin module serves for the administration of users and application setting.
- The Measurement module includes the definition of the measurement procedure and overall data management including viewing, adding, editing and deleting records.
- The Experiment module provides features for adding, editing and deleting experiments.
- Each experiment requires its own set of measuring devices. The Equipment module stores them in the database and provides tools for their management.
- The QR generator module generates QR codes into a PDF document given to the participant. Each person has his/her numerical identifier included in his/her QR code.
- The File Storage module provides an interface for uploading and downloading files.
- The Brain module serves for the P300 event-related potential data processing.
- The Reaction module has features for statistical processing of hand and leg reaction time and graph view.
- The Cardio module computes basic statistics from heart and blood data
- The Respiration module shows statistics from spirometry and stress spirometry data.
- The Fitness module is processing body for proportion, strength and balance data.

While the Brain and Fitness modules were newly designed, implemented and integrated within the software system, other modules were only partly redesigned and reimplemented.

3.3 Testing

The software prototype has been tested on 124 healthy participants both in lab and non-lab environment (e.g. during the Days of science and technologies 2017 that were held on the Pilsen main square in September 2017) according to the following procedure.

After registering and signing the informed consent within the mobile application, each participant obtained a QR code ticket and continued to fill in an electronic motivational questionnaire containing a set of 19 single choice questions to provide a basic overview of participant's current lifestyle and health condition. Immediately after that participants took part in individual measurements organized at nine individual sites located in a big tent. Each site was equipped with appropriate hardware and software tools related to the specific measurement. It was operated by at least one human expert who also provided the participant with information about the related measurement. There was an information desk that served both for registration of participants and provision of measurements results.

Although there was a recommended route between individual measurement sites, in fact, the participants could visit them in any order (see the schema of measurement sites and the recommended route in Figure 2). They were also not required to complete all the measurements and could have interrupted the measurement cycle at any time. Only in the best case they visited all the measurement sites and filled in all questions in the questionnaire. The complete data collection procedure took approximately 30 minutes.

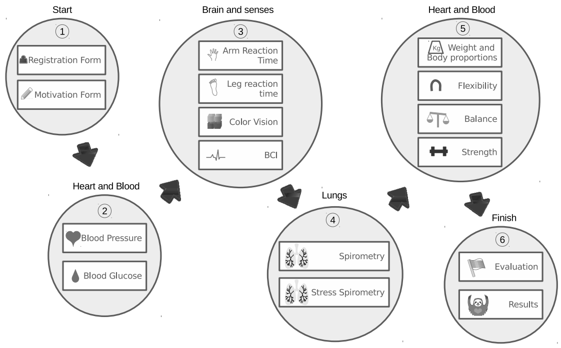

Figure 2: Schema of measurement sites and recommended route between them.

When a single measurement was completed (see e.g. the schema for the Brain and senses measurement site in Figure 3), the obtained data were inserted using the web interface into the BodyInNumbers software system. When the participant finished his/her last measurement, he/she was provided with the results (measured values) from all visited measurement sites. The results were organized on the web page according to the participant's QR code.

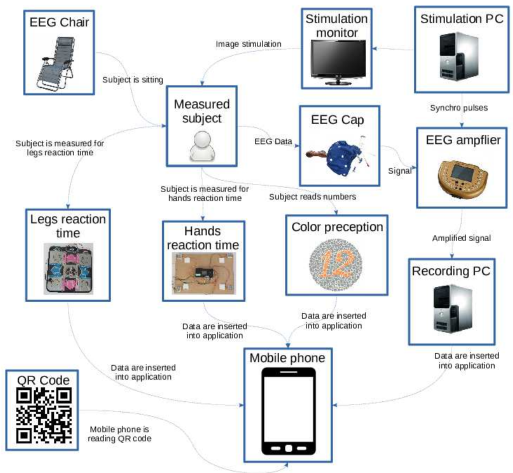

Figure 3: Schema of the measurement site Brain and senses.

4 CONCLUSIONS

In this paper we presented an extension of the BodyInNumbers software system for the exercise and wellness health strategy framework. This software system serves not only for rapid collection of health related data but finally for the wellness intervention program aiming at modifiable lifestyle factors that often contribute to incidence of chronic diseases. The most important extended parts of the software system include the definition of the user roles that have a direct impact on the security of the data and metadata stored in the system and design, implementation and integration of the Brain and Fitness modules that enable greater variability of collected data and metadata. The system functionalities were validated during its real deployment.

The next steps in the system design and development include the revision of used terminologies and extension of data processing methods. The system is planned to be deployed within an intervention program to store, analyze and visualize health-related data and their interpretations.

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REFERENCES

Afshin, A., Forouzanfar, M. H., Reitsma, M. B., Sur, P., Estep, K., Lee, A., Marczak, L., Mokdad, A. H., Moradi-Lakeh, M., Naghavi, M., et al. (2017). Health effects of overweight and obesity in 195 countries over 25 years. *The New England journal of medicine*, 377(1):13–27.

Allan, L. M., Ballard, C. G., Rowan, E. N., and Kenny, R. A. (2009). Incidence and prediction of falls in dementia: a prospective study in older people. *PloS one*, 4(5):e5521.

Andel, R., Crowe, M., Pedersen, N. L., Fratiglioni, L., Johansson, B., and Gatz, M. (2008). Physical exercise at midlife and risk of dementia three decades later: a population-based study of swedish twins. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 63(1):62–66.

Bolandzadeh, N., Kording, K., Salowitz, N., Davis, J. C., Hsu, L., Chan, A., Sharma, D., Blohm, G., and Liu-Ambrose, T. (2015). Predicting cognitive function from clinical measures of physical function and health status in older adults. *PloS one*, 10(3):e0119075.

Bruha, P., Moucek, R., Šnejdar, P., Bohmann, D., Kraft, V., and Rehor, P. (2017). Exercise and wellness health strategy framework. *BIOSTEC 2017*, page 477.

Chmelík, F., Frömel, K., Křen, F., Stelzer, J., Engelová, L., Kudláček, M., Mitáš, J., et al. (2017). International database for research and educational support. Indares.com. Online; accessed 2017-10-06.

Conn, V. S. (2010). Depressive symptom outcomes of physical activity interventions: meta-analysis findings. *Annals of behavioral Medicine*, 39(2):128–138.

Dunn, A. L. (2010). exercise programmes reduce anxiety symptoms in sedentary patients with chronic illnesses. *Evidence-based mental health*, 13(3):95–95.

Ellison, J., Nagamuthu, C., Vanderloo, S., McRae, B., and Waters, C. (2016). Estimating chronic disease rates in canada: which population-wide denominator to use? *Health promotion and chronic disease prevention in Canada: research, policy and practice*, 36(10):224.

Fenesi, B., Fang, H., Kovacevic, A., Oremus, M., Raina, P., and Heisz, J. J. (2016). Physical exercise moderates the relationship of apolipoprotein e (apoe) genotype and dementia risk: A population-based study. *Journal of Alzheimer's Disease*, (Preprint):1–7.

Grasgruber, P., Sebera, M., Hrazdira, E., Hrebickova, S., and Cacek, J. (2016). Food consumption and the actual statistics of cardiovascular diseases: an epidemiological comparison of 42 european countries. *Food & nutrition research*, 60(1):31694.

HAPPYneuron, G. S. (2017). My happy neuron. happyneuron.com/. Online; accessed 2017-10-06.

Harris, A., Waage, S., Ursin, H., Hansen, Å. M., Bjorvatn, B., and Eriksen, H. R. (2010). Cortisol, reaction time test and health among offshore shift workers. *Psychoneuroendocrinology*, 35(9):1339–1347.

Kokkinos, P., Sheriff, H., and Kheirbek, R. (2011). Physical inactivity and mortality risk. *Cardiology research and practice*, 2011.

Lee, D.-c., Artero, E. G., Sui, X., and Blair, S. N. (2010). Mortality trends in the general population: the importance of cardiorespiratory fitness. *Journal of Psychopharmacology*, 24(4_suppl):27–35.

Matura, S., Fleckenstein, J., Deichmann, R., Engeroff, T., Füzéki, E., Hattingen, E., Hellweg, R., Lienerth, B., Pilatus, U., Schwarz, S., et al. (2017). Effects of aerobic exercise on brain metabolism and grey matter volume in older adults: results of the randomised controlled smart trial. *Translational psychiatry*, 7(7):e1172.

Rizzoli, R., Bruyère, O., Cannata-Andia, J. B., Devogelaer, J.-P., Lyritis, G., Ringe, J., Vellas, B., and Reginster, J.-Y. (2009). Management of osteoporosis in the elderly. *Current medical research and opinion*, 25(10):2373–2387.

State of Play games (2014). Lumino city. luminocitygame.com/. Online; accessed 2017-10-06.

Teri, L., Gibbons, L. E., McCurry, S. M., Logsdon, R. G., Buchner, D. M., Barlow, W. E., Kukull, W. A., LaCroix, A. Z., McCormick, W., and Larson, E. B. (2003). Exercise plus behavioral management in patients with alzheimer disease: a randomized controlled trial. *Jama*, 290(15):2015–2022.

Thomas, D. R. (2010). Sarcopenia. *Clinics in geriatric medicine*, 26(2):331–346.

Vitabot.com (2017). Vitabot, online meal planning. vitabot.com/web. Online; accessed 2017-10-06.