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Evaluating the impact of a service-oriented framework for healthcare interoperability

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Abstract. This paper describes the evaluation of a service-oriented prototype implementation. The prototype development aims to exploit the use of service-oriented concepts for achieving healthcare interoperability while it also attempts to move towards a virtual patient record paradigm. The proposed evaluation strategy investigates the adaptation of the DeLone and McLean model of information systems success with respect to service-oriented implementations. Specific service-oriented and virtual patient record characteristics were empirically encapsulated in the DeLone and McLean model and respective evaluation measures were produced. The proposed theoretical framework was utilized for conducting an empirical study amongst sixty two participants in order to observe their perceptions with respect to the hypothetical adoption of the prototype framework. The data gathered was analyzed using partial least squares. The generated results highlighted the importance of information quality whereas system quality did not prove to be a strong significant predictor in the overall model.

Keywords. interoperability, process, assessment-evaluation: IS success model, DeLone and McLean, partial least squares

Introduction

The evolution of technology in the healthcare context consequently leads to both experimental and productive adoptions of new information technology (IT) standards in the healthcare domain. A typical field of health informatics related with such adoptions is interoperability. Healthcare interoperability includes several aspects under consideration since it is associated with a variety of concerns, perceptions and approaches whereas it also involves several standards, methods, stakeholders and roles [1].

A service-oriented prototype implementation was developed at the health informatics laboratory, Faculty of Nursing, University of Athens [1]. The aim of the prototype implementation is twofold. Primarily to investigate the adaptation of service oriented architectures (SOA) [2-4] for achieving healthcare interoperability. Secondly, to propose a homogeneous Web-based environment, capable of presenting the dynamic

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unification of distributed patient data, through the orchestration of services from a diversity of applications. Consequently, the prototype implementation attempts to formulate a virtual patient record (VPR) approach [1]. Moreover, the research work exploits the use of the business process execution language (BPEL) standard for the design and implementation of business and technical processes that coordinate software services in order to achieve interoperability in healthcare organisations [2,5].

Related work in this field includes initiatives and propositions for VPR implementations [6,7] and service-oriented computing in healthcare [3,4,8,9]. However, equal attention should be paid in the evaluation of technological adoptions in healthcare, in order to ensure the success and effective use of any information system development [10]. The work described in this paper aims to move towards an evaluation strategy for SOA implementations with VPR functionality in the healthcare domain.

The presented work is organised in several sections. Section 1 outlines the research model and method. Section 2 focuses on the data analysis approach. Section 3 presents the results obtained and provides a discussion on the methodology in terms of the measurement and the structural model. Section 4 provides a discussion on the results and the outcomes of the study. Finally, Section 5 presents future adoptions of the SOA prototype framework and the proposed evaluation approach.

1. Research model and method

1.1. Theoretical framework

The theoretical background for conducting an evaluation of the SOA prototype is based on the initial proposition of the DeLone and McLean information systems (IS) Success model [11]. The current study attempts to utilize the IS Success model in the context of a hypothetical adoption, since the SOA framework under evaluation is a prototype. Regardless of the empirical encapsulation of SOA and VPR characteristics within the dimensions of the DeLone and McLean model, the objective is to observe and comment on the trend and the perception that such a prototype might create amongst participants with clinical and/or informatics background.

In their model, DeLone and McLean define six dimensions namely system quality, information quality, use, user satisfaction, individual impact and organisational impact [11]. By definition, the dimensions of system and information quality both affect the dimensions of use and user satisfaction respectively. Furthermore, use and user satisfaction affect each other while both also affect the dimension of individual impact and finally, individual impact affects organisational impact [11-14]. In the context of the current study, the characteristics that contribute to the six dimensions defined by DeLone and McLean are formulated from a SOA and VPR perspective, combined with various relevant characteristics from the influential studies of Iivari [12] and Yusof, Paul and Stergioulas [15]. Thus, for each dimension, specific characteristics are proposed in an attempt to reflect service-oriented and virtual patient record attributes.

1.2. Service-oriented characteristics and hypotheses

Regarding system quality, the selected characteristics were flexibility, usefulness, interoperability, maintainability, scalability and reusability. The selection of the first

three attributes was influenced from the propositions of Iivari [12] and Yusof et al. [15] whereas the last three are proposed in an attempt to reflect possible SOA characteristics and architectural advantages [1,2,5]. Concerning information quality, characteristics include data completeness, data unification, semantically mapping capabilities, consistency of the actual content, data standardization and relevancy of the consolidated data. In a similar manner, the selection of completeness, consistency and relevancy was influenced from Yusof et al. [15] and Iivari [12]. The remaining attributes were selected in an attempt to reflect possible VPR characteristics. Continuously, the rest of the dimensions, namely use, user satisfaction, individual impact and organisational impact, were formulated based on a subjectivist manner.

The dimension of use is related with attributes that attempt to measure the potential use of the prototype, due to its hypothetical nature. Furthermore, for user satisfaction, the current study attempts to include characteristics related with the understanding and the possible innovative nature of the overall architecture, the interest on the proposed model, and finally the perception regarding its capabilities for achieving interoperability. The dimension of individual impact introduces measures related with possible time saving for accomplishing individual tasks, harmonization of daily activities with the overall business process model in a healthcare organisation, usefulness of a SOA framework as both a business and technical tool and finally, individual perceptions regarding productivity and work performance improvement. At last, the dimension of organisational impact formulates a set of attributes that are associated with possible cost implications, business process (re) engineering and/or (re) design along with possible overall time savings from an organisational perspective, in an attempt to investigate such concepts.

The following hypotheses were formulated: System quality affects user satisfaction (H1), information quality affects user satisfaction (H2), system quality affects use (H3), information quality affects use (H4), use affects user satisfaction (H5), user satisfaction affects use (H6), user satisfaction affects individual impact (H7), use affects individual impact (H8) and individual impact affects organisational impact (H9) [12].

2. Data analysis

The prototype nature of the proposed framework creates several limitations. Thus, the sample selection for conducting an evaluation had a limited scope. Mainly, it was based on past and present postgraduate students specializing in health informatics and healthcare services management at the Faculty of Nursing, University of Athens. The undergraduate background of the students was nursing or informatics science. Also, a minor set of participants originated from either nursing departments of healthcare organisations or the healthcare IT industry, and agreed to participate in the study in an individual basis. The empirical assessment included sixty two participants. A significant percentage of the sample (35.5%) was employed in healthcare organisations.

The formulated sample provides the opportunity to obtain hypothetical, but still useful beliefs and perceptions regarding the proposed framework. A short introduction on design issues and a live demonstration scenario of the prototype were presented to the evaluators. Afterwards, participants were asked to complete an anonymous questionnaire. System quality, information quality, use, user satisfaction, individual impact and organisational impact were related with SYSQ (24 measures), INFQ (24 measures), PU (2 measures), PUS (6 measures), INDV (6 measures) and ORG (6

measures) accordingly. All measures were modeled in a 7-scale Likert approach. In general, the number of measures per dimension and the scaling in the questionnaire were adopted from Iivari [12].

The data gathered was analyzed using structural equation modeling, specifically partial least squares (PLS) which is mainly used for prediction rather than confirmatory analysis [12,17] and is utilized in several research works [12,13,18-20]. For the modelling and the data analysis, the software package smartPLS version 2.0 M3 beta was used [16]. The dimensions and characteristics were described as a second order model with two scenarios in smartPLS software, in order to adequately reflect the bi-directional interaction between the dimensions of use and user satisfaction (use to user satisfaction and user satisfaction to use respectively) [12].

3. Results

The generated results were assessed according to the measurement and the structural model [12, 13, 17-20].

For the measurement model, individual item loadings, construct reliability (internal consistency), convergent validity and discriminant validity were investigated. Regarding individual item loadings, 66 out of 68 overall items exceeded 0.6, with 61 of them producing a value greater than 0.7, thus considered reliable [12,13,18-20]. Only two items produced values below 0.6 in both scenarios, but can be considered acceptable since they exceed the threshold value of 0.5 for acceptable results [19,20]. Construct reliability assessment was based on Cronbach's alpha and composite reliability. All values were considered reliable (exceeded 0.7 for Cronbach's alpha and 0.8 for composite reliability) [12,13,18-20], except the value of Cronbach's alpha for use (0.5976). In the case of convergent validity, the values of the average variance extracted (AVE) were observed, as proposed by Fornell and Larcker [21] [12,13,19]. All constructs produced an AVE that exceeded 0.5 [12,13,18-20], except system and information quality (0.4048 and 0.4298 respectively), which may be explained from the molar nature of the model [12]. At last, for the assessment of discriminant validity, all constructs produced satisfactory results for the square root of the AVE [12,13,18-20], except interoperability (0.7792 compared to 0.8459), scalability (0.8004 compared to 0.8233 and 0.8236), flexibility (0.7924 compared to 0.806 and 0.8063) and reusability (0.7973 compared to 0.8602). Additionally, system and information quality did not produce satisfactory results (0.6362 compared to 0.7678 and 0.7721 for system quality and 0.6555 compared with 0.8504 and 0.8506 for information quality in both scenarios).

Regarding the structural model, a resampling technique was used, based on bootstrapping (500 resamples) [12,13,17,18,20]. The examination of the t-values was based on a two-tail test with statistically significant levels of $p<0.05$ (*), $p<0.01$ (**) and $p<0.001$ (***). The results are shown in Figure 1. The upper value per pair concerns the first scenario whereas the lower value the second scenario respectively. Dotted lines emphasize the paths that did not prove to be significant in both scenarios and consequently the hypotheses that were not confirmed.

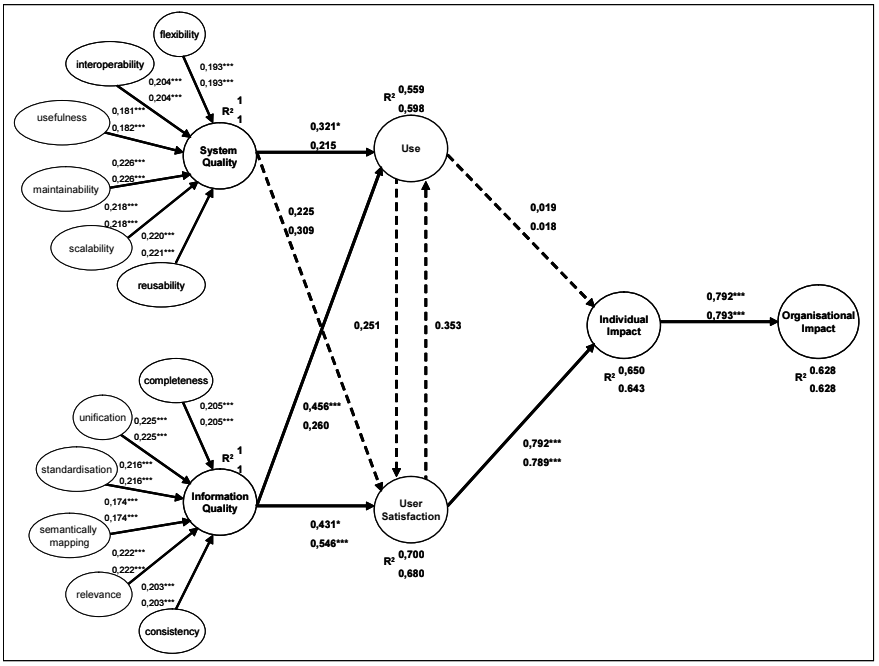

Figure 1. Results of the structural model (Source: Adopted from Daskalakis [22])

4. Discussion

The evaluation results highlighted that system quality is partially a predictor of system use but not of user satisfaction. Moreover, system use did not prove to be a significant predictor of individual impact. On the contrary, information quality proved to be a significant predictor of user satisfaction and partially a significant predictor of system use as well. Furthermore, the bi-directional relation between use and user satisfaction did not confirm in the context of the current study. In addition, user satisfaction found to be a strong predictor of individual impact. Finally, the dimension of individual impact was found to be a strong significant predictor of organisational impact. Such findings may highlight that participants tend to focus more on the quality of the information provided than the characteristics that govern the technology used for the information provisioning.

5. Conclusions

A service-oriented interoperability prototype with VPR capabilities has been developed and evaluated, based on a hypothetical adoption. Future work in the current field includes the prototype adoption in real healthcare conditions. Its impact can be investigated by conducting empirical assessments with distinct stakeholder groups. Overall, the propositions described in the current paper may be potentially adjusted in a variety of healthcare organisations in order to promote the evaluation of service-oriented implementations with virtual patient record capabilities.

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