How to measure the QoS of a Web-based EHRs system: Development of an instrument

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Abstract

The quality of service (QoS) can be treated as a set of concepts whose satisfaction/dissatisfaction generates a global positive/negative vision about the service provided by any application. The different nature of the services and its features require an analysis of the factors that have the greatest influence on the users' opinion and, therefore, measuring the quality of service in each application requires a specific instrument.

This paper will introduce an instrument to measure the QoS offered to users by a general Web application for Electronic Health Records (EHRs). The collection of opinions from a pilot sample and the performance of an explanatory factor analysis will bring together the factors that best sum up the quality of an EHRs application. Subsequently, a confirmatory factor analysis will be performed to make the study reliable and, as its name suggests, to confirm that indeed the structure of the instrument developed measures the QoS in accordance with the requirements of the users.

Keywords: Dimensions; Electronic Health Records (EHRs); Factor analysis; Goodness of fit indexes; Quality of service (QoS).

1. Introduction

In recent years, the medical environment has been in a period of continuous evolution. Scientific researches and the development of new methods have turned health into one of the most important fields. Modest discoveries have a worldwide impact and open many doors, despite they might have seemed insignificant at first glance. It is not hard, therefore, to infer that the boom of medical advances can be defined by a single word: Collaboration.

The advent of the Web 2.0 has shown the value of a real Multimedia Internet or Content Internet in several fields, especially in the medical area (1). The distinguishing element of the Web 2.0 with respect to the old Web concept is the growing participation of users. In the last years users are no longer merely content readers, as they have moved to actively contribute to create those contents. Individuals can express value judgements, upload their photos, videos or even develop their own applications for the use and benefit of the rest of users.

In e-health, the evaluation involves attempts to answer a wide range of questions involved in making decisions about safety, about practicality and about utility. Most of the studies to establish the practicality of telemedicine services have been carried out as demonstrations, to show that a proposed application can be implemented in a chosen setting (2). Many hospitals are currently in the process of developing and implementing Electronic Health Records (EHRs) systems (3-5). This is a critical time for developing a framework that can measure and allow for comparison the effectiveness of EHRs systems across hospitals that have implemented these systems (6-8)

An EHRs application is merely just one of the hundreds of initiatives to take advantage of the huge potential of the Web 2.0 (9-12). Nevertheless, it is still very difficult for the general public to enjoy these interactive content services on the Internet, especially when it comes to produce, share and spread contents. For this reason, the revolutionary ideas have not made headway, falling into oblivion in favour of the most traditional methods.

The quality of service (QoS) and, therefore, the satisfaction of the client/user must at all times be the eventual goal in the development of any application. In fact, this study aimed at quantifying the QoS so that developers can support their design decisions on a scientific basis.

Since 1998 the measurement of the QoS has caused concern among researchers [(13-15)]. Due to the different nature of the services, the instruments for their quantification cannot be the same in all cases. The examination of the studies and the thorough analysis of the methods have resulted in the development of an instrument in the form of survey, whose distribution among users may provide clear measurements of their satisfaction.

The points we shall address in this article are: we will talk about the background to this paper in 2 points, and we will describe the methodology used in 3 points. Then, we will show the results of the factor analyses. We will end with conclusions on the results obtained in the research and the future work.

2. Background

The list of researches associated with the quantification of the QoS may be too long to reproduce here [(16-17)].

Parasuraman, the precursor to this trend with his SERVQUAL model, identified the quality of service as the gap between the user's perception and expectations with reference to several aspects that we could call dimensions. These dimensions were formed by sets of questions or items that try to describe characteristics such as reliability, responsiveness or the security of the service. This set of dimensions was named "constructo" [(15)].

Later models advocated that the measurement of perceptions was a more reliable model. Thus, SERVPERF – with a similar structure to SERVQUAL [18-19] – would guide the steps of the models to come. This was followed by several and varied instruments to measure each of the possible services. A compilation of a few researches that have been carried out to date is displayed in the Table 1.

Table 1. Documentation about the QoS on the Web [13].

Year	Study area	Dimensions
2002	Quality of general information websites	Fit of the information Interactivity Confidence Response time Readability Intuitive operation Visual appearance Innovation Emotional appearance Consistency Integrity Quality regarding competence
2002	Use of web portals	Contents Customisation Reliability Security
2002	General web services	Competitiveness Quality of the information Empathy Web assistance Maintenance systems
2003	B2C Portals	Customer service Information benefits Interactivity
2005	Online shopping	Efficiency Availability of the system Responsiveness Privacy Customer service

		Contact information
2005	Business portals	Usability Usefulness of the contents Fit of the information Accessibility Interactivity

A web-based EHRs system (for example, the TeleOftalWeb service [20-21]) might be one of the earlier-mentioned web applications, but for its health environment. For this reason, we decided to develop a specific instrument that could not be defined by the existing ones and that was expected to extend its application to other EHRs web services.

3. Methodology

Initially, a battery of 50 questions was made referring to different aspects of the service provided by a general EHRs web application. The previous revision to the distribution of the initial survey brought forward a questionnaire with 40 items that users had to rate using a 7-point Likert scale.

Within an initial analysis, the survey was distributed in June 2011 among users of an EHRs web system who had previously been given access to the application to rate it.

A total of 243 responses were collected, out of them, 180 of them were valid. To refine the instrument, an exploratory factor analysis (EFA) was performed to identify the underlying factors or dimensions modelling the quality of service. The instrument was examined using Varimax rotation to facilitate the interpretation of the factors generated by the principal components technique with Kaiser normalisation.

Regarding the second analysis, the refined survey was distributed in September 2011 in accordance with the same methodology of the first analysis. Of the total 220 responses, 206 (93.6%) were valid, which represents a great improvement with respect to the 74% of the pilot survey. This is to be explained by the elimination of items associated with technical characteristics of the system, which might have been ignored by users.

4. Development and validation of the instrument

4.1. Exploratory factor analysis

The first analysis showed the existence of 15 factors that explained the QoS in the application. Also, it showed factor loadings of certain items on many factor or factors explained by a single item. For this reason, it was required to eliminate 11 items in two rounds. The next step was to characterise the dimensions according to the remaining items. As it was impossible to characterise three of the factors, 7 new items had to be eliminated. This resulted in an initial instrument formed by 7 perfectly-characterisable dimensions with eigenvalues larger than unity and a total of 22 items. The Table 2 shows the details of the retained factor loadings.

Table 2. Results of the exploratory factor analysis in the initial study.

		1	2	3	4	5	6	7

P1	The information is relevant.					.707		
P5	The information contains reliable professional opinions.					.879		
P6	The information is up-to-date.					.660		
P8	The application covers the required functions.				.807			
P10	The application saves me time.				.819			
P11	The application makes my work easier.				.786			
P14	The browser is intuitive.	.837						
P15	The desired information is easy to find.	.855						
P19	The creation and modification of Records is easy and complete.	.771						
P20	Printing EHRs is easy and accurate.	.798						
P22	It makes the exchange of views easier.							.890
P23	It is easy to share contents.							.902
P29	The use of fonts is adequate.		.777					
P30	The use of colours is appropriate.		.854					
P31	The use of multimedia images and contents is appropriate.		.843					
P32	The general appearance of the application is appealing.		.678					
P34	The confidentiality and privacy of the patients' information is maintained.						.775	
P35	The access to the application is secure.						.854	
P36	The integrity of the information is ensured.						.711	
P38	The service is always available.			.891				
P39	The application provides the records within a reasonable timeframe.			.797				
P40	The information is accessible from any network point.			.791				

The Kaiser-Meyer-Olkin measure was 0.671, above the recommended 0.5 threshold, which ensures that the sample is adequate. Also Bartlett's test of sphericity showed meaningful values, thereby providing support to the validity of the instrument [22].

To complete the analysis, Cronbach's alpha values were measured for each dimension, with the minimal α being 0,704, above the recommended 0,70 threshold. Moreover, the minimum correlation between item and total was 0.461, above the recommended value of 0.4. Therefore, the reliability of the factors was ensured and, as it is shown in the Table 3, the elimination of any of the factors is not recommended in order to improve the respective Cronbch's alpha values. In conclusion, the refined instrument explained 69.776% of the cumulative variance.

Following this first analysis, the quality of service in a web application for EHRs exchange was represented by 7 dimensions: Quality, Browsability, Usefulness, Interactivity, Style, Security (including Privacy and Confidentiality) and Availability.

Table 3. EFA results for the refined instrument.

	Item-Total Correlation	**Cronbach's α if the item is eliminated**	**Cronbach's α**

Quality of the information (CAL)	P1	.597	.563	.720
	P2	.546	.624	
	P6	.494	.687	
Usefulness of the information (UTL)	P8	.573	.649	.741
	P9	.608	.608	
	P11	.526	.702	
Browsability (NV)	P14	.709	.773	.836
	P15	.714	.777	
	P19	.617	.815	
	P20	.641	.805	
Interactivity (IN)	P22	.659	.801	0.791
	P23	.659	.799	
Style/ Appearance (ES)	P29	.580	.771	0.802
	P30	.697	.719	
	P31	.687	.719	
	P32	.525	.801	
Security (SG)	P34	.487	.653	.704
	P35	.622	.476	
	P36	.461	.688	
Availability (DIS)	P38	.670	.724	.809
	P39	.685	.714	
	P40	.629	.773	

4.2. Confirmatory Factor Analysis

The next step was to find a new approach to a Confirmatory Factor Analysis (CFA) to check the validity of the instrument. The use of the software AMOS 17.0 brought forward a structure of the instrument shaped as in the Figure 1.

This model showed a chi-square fit index of 290 with 188 degrees of freedom. The goodness-of-fit index (GFI) was 0.877, as the value for adjusted goodness-of-fit index (AGFI) was 0.835. Likewise, the comparative fit index (CFI) was 0.917 whereas the Tukey's test showed a value of 0.898. Finally, the root-mean-square error of approximation (RMSEA) showed a value of 0.054.

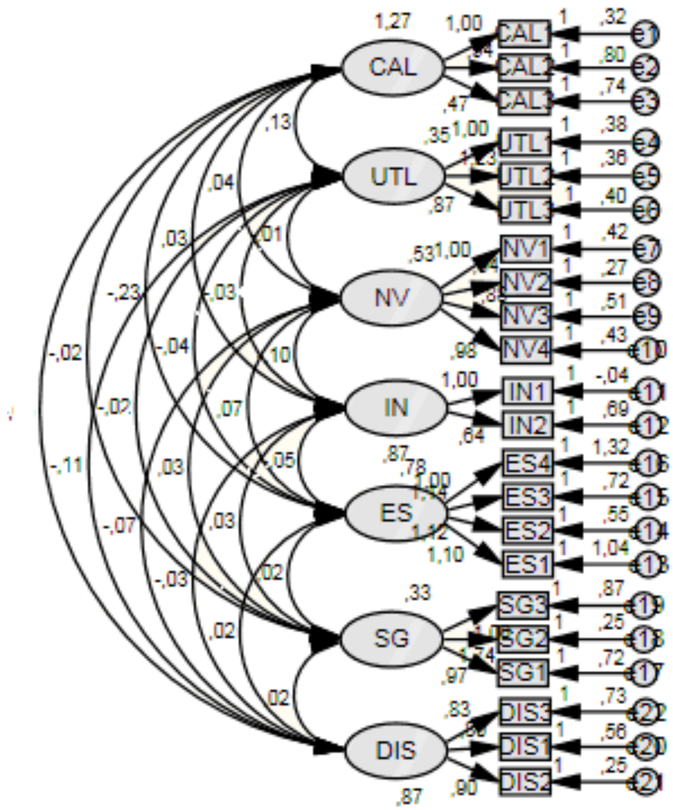

Figure 1. First-order factor structure.

The values TLI, GFI and CFI should be greater than 0.9 whereas the value AGFI should be higher than 0.8. Also, the RMSEA value should not be greater than 0.08. For all this, we could conclude that the fit of the model was not good and a reassessment was required to adapt it to the QoS measure for web applications of EHRs exchange.

The analysis of the matrix of standardised residuals identified values greater than 2.58, revealing prediction errors [10]. This, together with a high modification index between DIS3 and CAL2, showed a great correlation between the dimensions of information quality and availability. The results supported the deletion of items, which yielded a significant improvement in the goodness-of-fit indexes, with a CFI of 0.944, a GFI of 0.898, a AGFI of 0.860 and a Tukey's test (TLI) scoring 0.931. These values indicated that the model required a new re-specification. The analysis of co-variance of the error terms in the items of the dimension of information quality was particularly high, which is a clear sign of the low level of differentiation between dimensions among the perceptions of the respondents [15]. It was decided to eliminate the dimension discussed earlier. The new analysis of the model, therefore, showed the factor structure of the Figure 2.

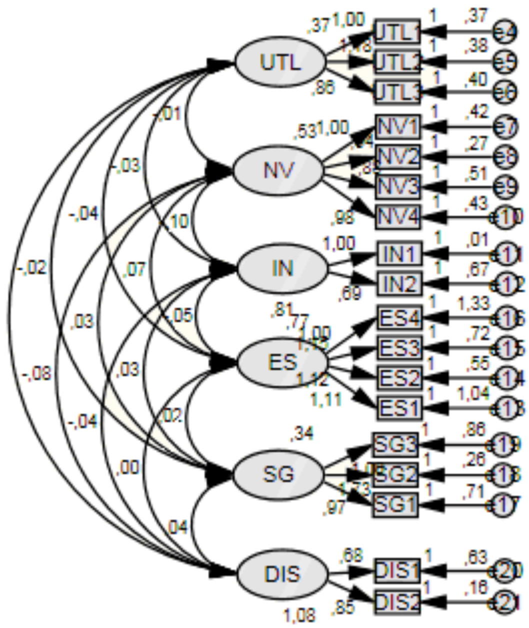

Figure 2. Re-specification of the factor structure.

On this occasion the results were more encouraging, achieving values that supported a high goodness of fit for the model as it shows the Table 4.

It should not be forgotten that the ultimate aim of the analysis was to develop an instrument to measure the quality of service. Therefore, it is assumed the existence of a second-order factor that would explain the first-order factors or dimensions shown above [(1)]. Thus, the second-order model shown in the Figure 3 was proposed to conclude the analysis.

Table 4. Goodness-of-fit indexes of the instrument developed.

	Instrument developed	Recommended threshold
GFI	0.926	0.9
AGFI	0.885	0.8
TLI	0.953	0.9
CFI	0.965	0.9
RMSEA	0.031	0.08

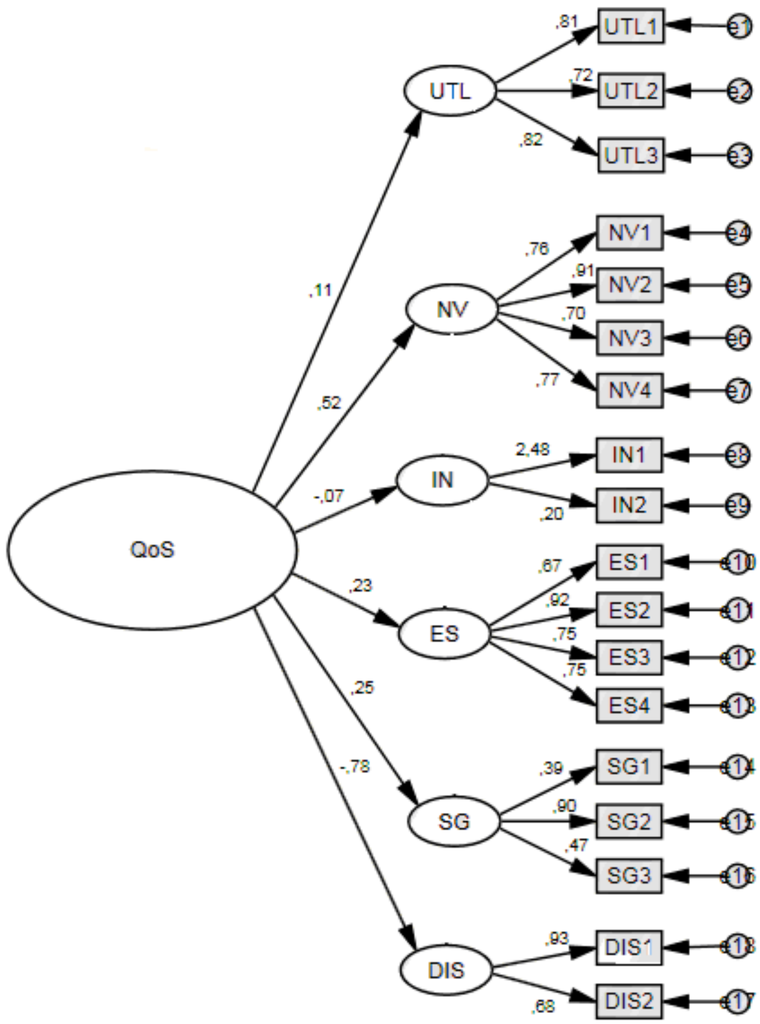

Figure 3. Second-order factor model.

The data collected did not do nothing but corroborate the observations derived from the earlier analysis, with the model yielding an excellent goodness-of-fit. In this occasion, the chi-square goodness of fit index was 417.297 with 129 degrees of freedom. The goodness-of-fit index (GFI) was 0.992 and its adjusted value (AGFI), 0.990. Also the comparative fit index (CFI) was 0.956 and the Tukey's test produced a value of 0.948. Finally, the root-mean-square error of approximation (RMSEA) was 0.079. Therefore, as we wait for future invariability tests between demographic groups with more users of the application, we can conclude that the instrument developed presents an outstanding fit to the requirements of the application.

5. Conclusions and Future Work

The examination of the analyses and the thorough study of the methods have resulted in the development of an instrument that takes the form of a survey that, once distributed among the users, can offer clear measures of their satisfaction.

The final instrument consists of 18 items divided in 6 dimensions and will provide completely reliable measurements of the perceptions of the doctors using the application. It was concluded that out of all the characteristics of the application, its usefulness, browsability, interactivity, security, appearance and availability had the greatest impact on users' opinion over others such as quality of information, technical features or the personalisation of contents.

Regarding the correct fit of the solution to the characteristics of the application, the conclusions are obvious, as the goodness-of-fit indexes performed above the limits established in several studies in this field and above those others set by the experience.

Hence, we can conclude that the background to this research is perfectly justified, establishing itself as a compulsory step to develop and improve future applications. The QoS on the Web 2.0 is crucial and its measurement is essential to the success of any application in the wake of increasing competition.

Nowadays, we are developing a telematic instrument to facilitate the statistics analysis in the different phases. As future work, more real users of different Web-based EHRs systems (commercial and open-source) would be able to validate the tool.

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Conflict of Interest

The authors declare that there is no conflict of interest with the contents of this manuscript.

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