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A RELATIONAL STUDY ON INFORMATION VISUALIZATION FACTORS IN MULTIPLE ELECTRONIC HEALTH RECORDS

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ABSTRACT *Electronic Health Records (EHR) utilize Information Visualization (IV) for the efficient understanding and robust utilization by associated stakeholders such as DBA, Visual Designers and Doctors. Existing IV techniques, tools and applications address only on feedback from doctors while IV applications in the health domain involve the collaboration of multidisciplinary professionals. This study categorically addresses on the feedback from all three stakeholders based on an existing IV model CARE 1.0 for IV factors in knowledge, skills, assessment and future perspective. This research paper provides the analysis of three questionnaires based studies from three stakeholders' doctors, DBA and visual designers associated with multiple EHR tools. Linear relationship between individual and group wise distribution of all factors within each stakeholder and collaborative ones are presented with a discussion for proposition of an IV prototype.*

KEYWORDS: Information Visualization, EHR, DBA, Temporal Medical Data, Linear Relationship

I. INTRODUCTION

Electronic Health Records (EHR) provide temporal categorical and numerical patients data using different information visualization (IV) tools for doctors. Electronic Health Records work similar to the traditional patient files and patient record files still the same method adopted in most government hospitals to keep the patient records near their bed or with the on staff duty in the cabinet. Information Visualization is categorized in different sub branches such as Data Visualization, Software Visualization, Geo Visualization, Patent Visualization and Visual Informatics[1-4, 13-16].

Doctors act as primary stakeholders while DBAs, and visual designers play role of secondary stakeholders. Numbers, texts, color codes and statistical charts are different representation of temporal and non temporal patient information in any form of visualization[9-11]. Legends , graphs, figures, tables and various layout styles assist the stakeholders to understand the complex meanings of any event or situation based anomaly within the live or stored data using different queries.

DBA and Visual designers play important role in developing the health informatics applications, but are less considered involved during the phases of system development. Currently implied visualization applications only involve the doctors and medical professionals for development solutions for complex data understanding. Temporal query is usually explored involving different color coding structure, numbers format, chart/graphs, texts, figures and pictorial formats[4-7]. As patient details comprise of time oriented data based on synoptic details so it may contain some static and some dynamic information that can be changed and dependent on various allied factors. Static information is name, date of birth, sex and other demographic details while dynamic information contains heart beat, blood samples report about any particular content details such as iron and haemoglobin quantities profile.

While doctors are mostly interested in dynamic information in recommending different medicines based on knowledge extraction details such as reported via LOD, VieVisu, Life Line, Life Flow and TimeLines[13,16,23,25,29,30]. Existing applications are developed based on doctors and primary coronary medicines professionals. These applications focus on the use and adaptation of such visualization resources only by doctors thus stronger gaps are identified between integration of non medical professionals that are involved directly in developing such applications. These gaps related to knowledge, skills , assessment and future perspective factors are not based only for doctors but also for other stake holders such as visual designers and DBAs. Absence of a close integration of feedback from all three nominated stakeholders lead to individual stakeholder based applications that are operative yet difficult to encompass the need of current and future systems such as limitation of color codes for all HL7 or ICD10 standards[24,28-31].

Medical professionals involve other IT professionals in the development, upgradation and restructure of temporal and non temporal EHR applications for improved decision support systems. DBA and visual designer assist in developing visual queries that are more robust in sense of time saving and occlusion of unnecessary data details from the end users thus saving time and complexity contingencies. Currently at low cost budget hospitals with maximized number of patient's time becomes a constraint in operating decision support applications in the form of reduced visualization application due to minimal support of knowledge, skills, assessment and future perspective understanding for doctors as being non IT professionals [8-11]. These gaps can be assessed previously at individual stakeholders level, but that was not addressing the overall comparison of all stakeholders feedback.

DBAs and visual designers focus on improving the efficiency and data understanding of multiple patient details. Previous IV applications adapted for IV such as TimeLine, SOAP, Problem Oriented Medical Record (POMR), Event Flow, Life Flow, Delone Mclean Model and collaborative inputs from various other tools for visualizing events and data in multiple records[25-33]. These tools are developed based only on the input from doctors while lack the active contribution of other stakeholders. Such applications are more complicated for use by fresh doctors as based on lack in knowledge constraints, difficult to apprehend, lesser

effective in the assessment and poor future perspective. Some applications provide better patient details while other are better in operations, but missing the combined linkage between all factors together.

This research paper provides a support to previously suggested IV model CARE 1.0 as mentioned in the Figure 1 [14,33]. This model represents the presents all four componenets knowledge, skills, assessment and future perspective while this paper emphasizes on the existence of linkage based on all three stakeholders as mentioned in the results at a later section. Though previous work proved the existence of these four groups of factors but this paper proves the statistical analysis for the said groups for future IV applications.

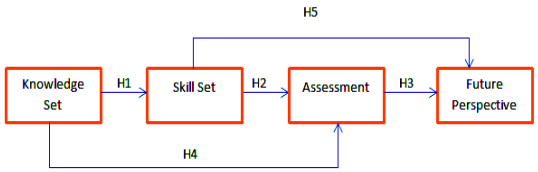


Figure 1: IV Model CARE 1.0 (S & Malik 2015)

This paper is comprised of five different sections: First section describes about the need of the existence and involvement of feedback from associated stakeholders. Section II presents the relevant work and visualization challenges in multiple EHR with reference to absence of feedback from other stakeholders than health professionals. Section III produces the details of the factors and studies conducted for individual group. Section IV describes the results and conclusion while section V highlights the future work areas.

RELATED WORK FOR EHR VISUALIZATION

EHR visualizations represent past patient records that are including their demographical details such as names, birthdate, location, past hospital visits, symptoms or disease identification, test reports and doctor's recommendations about medicines, treatment and operational details. Such resulting visualizations are normally developed and characterized based on the selected data field sets based on the end user requirements with the help of single or multiple patient records.

Patient details, problems description, synoptic prescription, recommendations and outcome of tests as updated patient disease biography for doctors with the help of health related databases. Existing IV applications Graphical User Interface (GUI) merely provides individual patient's demographical and organ/disease based patient information for robust decision support systems. Time Line, LifeLine1 & 2 and PatternFinder presents only a few events of single patient or multiple patient records that are showing only partial comparison[13-14,35]. Lack of knowledge, complicated operational skills, difficult assessment and incomplete future perspective lead to complex IV solutions development difficult to operate for novice and lesser experienced doctors. Past applications based on Pattern Finder as Figure 2 showed involvement of collaborative research based on multiple health industry stakeholders ,questionnaire based studies, focus group and interview based studies[30-35].

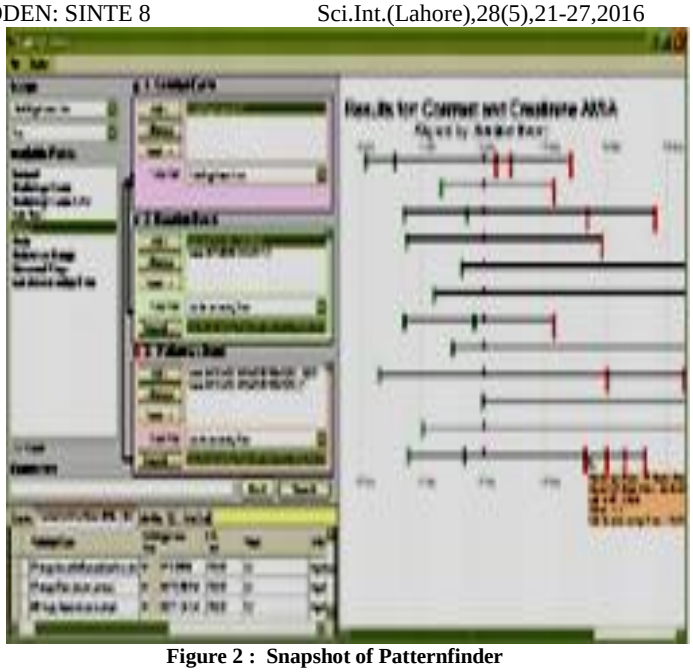


Figure 2 : Snapshot of Patternfinder
(C.Plaisant et.al 2008)

Health practitioners demand salient data features such as increased productivity, latest disease updates, trending in events, real time assessment for action oriented data and valuable future prediction in assessment both from implementation and funds point of views. Prefuse and ProtoViz are tools that tried to encompass the need of visualization features for single patient data rather than multiple thus focusing more on knowledge, but lesser on assessment and reduced effects observed in the domain of future perspective [7, 22-26]. Though both numerical and categorical temporal classified format of EHR assist in identifying the event based trends in patient data but missed interval based domain for long duration patient details. This result in complex GUI that makes the difficulty in data understanding and involves more time consumption from critical patient care measures. Timeline similar to other IV tools is another provision of multiple demographic and lab test results data, but only in single patient data[2]. This application is far better for experienced medical doctors, but lesser addressing the needs of database improvement in graphical interface solution for future visualization tools. Congestion of multiple events information also leads to increase the quantity of multiple faceted visual objects that hinders in understandabiltiy of the smooth operational capability by the end user.

Different results formations such as numbers, graphs, words, letters, codes, color charts, lines, pictures and shaded structures are frequently referenced in various visualization tools for better data understanding but lesser involves the combination of all stakeholders[17-20]. Most of visualizaiton applications depicts perceptual understanding of designers with colored metaphors, but lesser addressed on the joint needs of DBA thus missing the combined evaluation impact. This results in phase wise evaluation of EHR visualization based on medical data, but probes the absence of database features at some of the phases such as in LOD model as shown in Fig 3[25,27-29,34-35].

Figure 3: OutFlow *(K.Wong et.al 2011)*

International Disease Code(ICD) 9 & 10 are frequently used by different medical practitioners in different developed countries that are difficult to adapt in underdeveloped and minimum health spending health governing bodies. Gravi, ProtoViz and nested Model are some other applications based on non finite alogrithms involving the emergency care units[19-21]. Though granularity of information depicts more about the knowledge domain, but difficult to operate for complex visual queries thus limitizing the future scope. Regrouping, aligning and zooming of individual data was proposed by a subsequent event based IV applications based on the involvement of health informatics professionals rather than doctors only. This leads to the development of applications and future IV tools based on the combination of feedback from all three stakeholders. Thus a complete and intensive evaluation for better addressing of IV problems from designing, development and implementation grounds in low budget health hospitals and fresh medical graduates.

In this paper, the authors incorporated a similar HCI research procedures utilizing the questionnaire based studies as specifically used in development of IV tool based on feedback analysis from multiple stakeholders. This research paper presents in further sections a step ahead for analytical evaluation of relationship between four areas of IV such as knowledge, skills, assessment and future perspective.

II. MOTIVATION FOR THE STUDY

This research paper presents the evaluation as outcome of 3 different studies conducted on three different stakeholders involved with IV applications. This paper presents the supporting enhancement for already proposed existing proposed existing model CARE 1.0[14]. The proposed model as presented in Figure 1 represent Knowledge, skills, assessment and future perspective for IV applications as KNAVE [4] and V model [36].

LifeLine1 & 2, LifeFlow, Event Flow and AnamneVis focus on single and multiple HER, but only involve the feedback with lesser participants and sole users as doctors[23-26][30].

Feedback from DBA and Visual designers is a key input in addition to the feedback of doctors that is lacking in previous IV applications such as Amalga, RAVEL, and Prefuse. Prvious tools tried to address more on the need of doctors only involving them only while missing the DBA and designers[15, 19-25]. This result in highlighting the issues related to database and design of the multiple EHR associated with IV applications. Involvment of other stakeholders will strengethen the concept of developing solutions with increased customer satisifaction, improved knowledge and other allied phases of CARE 1.0[14,16].

One of the key objectives of this paper is to evaluate the needs of all stakeholders based on their feedback and other is to measure the combined effect of all factors associated with knowledge, skills, assessment and future perspective in any IV solution for multiple EHR.

III. RESEARCH METHOD AND STUDY DETAILS

In this research work, three detailed questionnaire based survey approach is adapted in a stratified sample 20 doctors working in emergency units of government hospitals, 20 DBA related to information system of health care units and 100 visual designers with 2-5 years of experience. These stakeholders are directly concerned with the interaction of EHR databases along with visualization application. Doctors, DBA and visual designers are different and important stakeholders and similar technique for individual group wise feedback has been adapted in previous studies. The gaps and areas of issues are same as used for all stakeholders in their case studies using literature review and expert's opinion of EHR visualization domain [14-18].

31 IV factors from 4 IV areas as mentioned in Table 2 are selected based on questionnaire mentioned in Table 1. Likert scale from 1-5, where 1 is representing poor or no understanding while 5 is for the expert level in that area of factor as similarly adapted in QUIS[13]. These are further categorized in four different groups and questionnaire is divided in further sections based on that division.The outcome of the survey based data is represented in the comparative analytical form in .

Table 1. Sample Qustionaire snapshot

Statement	Rating				
	5	4	3	2	1
Section IV: Assessment					
How much do you know how to use a visualization of EHR to train or share knowledge with other staff/fellows?					
How much do you know the strengths and weaknesses of EHR systems you use?					
How much do you know about creation, deletion, updation of entries or other knowledge extraction in EHR?					

Table 2. Different IV Factors related EHR

- IV tools knowledge
- Existing IV tool
- Data transformation IV tool
- IV data handling tecniques
- Non temporal data visualization
- Single patient record visualization
- Multiple patients data visualization
- Color mapping
- Fields visualization
- Visualization architecture
- IV creation
- IV updation
- EHR Representation
- Errors identification
- IV Amendment
- Temporal data Representation
- Color and pattern Understanding
- Missing Information
- Efficiency Measurement
- Point of interest
- Visualization Design
- Layout weakness
- Poor data extraction
- Functionality metrices
- Complete solution
- Ease in understanding
- Level of extensive info
- Simplification in operation
- Information sharing
- User friendly GUI
- Multiple Data flow

Tables 3 and 4 is representing the group wise statistical analysis in the aspect of correlation between knowledge, skills, assessment and future perspective as an average calculated for all 147 participants feedback. SPSS is used as a statistical tool to evaluate the analytical relationship beteween all the four groups. One column is representing the variables and rows are showing the values between 0 to 1. The value of 1 is showing the same or closely related items while the difference lies lesser than value of 1 shows the level of closeness and relation related to that variable. If values are lesser than .60 it shows that there is no significance observed between variables.

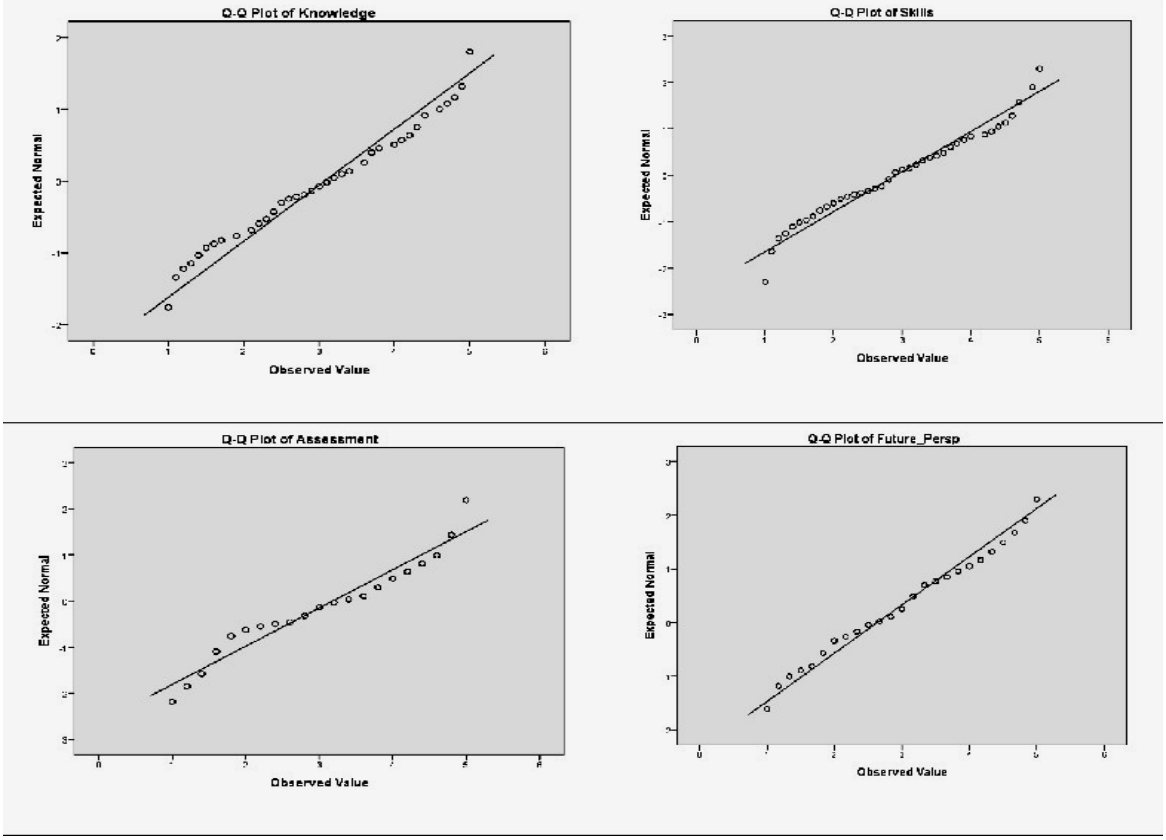
Four categorical variables mentioning the groups of IV factors termed as Knowledge, skills, assessment and future perspective are mentioned on both columns and rows wise distribution. Correlation is a statistical representation of fluctuation between two variables either positively or negatively. In positive correlation, significant values show that increase in values of one variable also depicts an increase in other variable while in the negative correlation change in one variable fluctuates negatively the other variable. Values of chronbach alpha were found 0.86 that is above, then 0.70 that shows the internal consistency of the questionnaire based tool itself [11,28]. Table 4 mentioning normality tests and standard deviation are reported for all four groups lying between 1.11 to 1.28 while skewness ranges from -.271 to .51 for all four groups. These values are aggregated against the number of factors for each group and then processed statistically to better understand the cumulative effect and the relationship between each group and stakeholders.

These factors were also highlighted in past research papers and also in previous work conducted on CARE1.0 [4,9,11,19-20,24,30-34]. The results of these studies will facilitate in validating the existence of the CARE1.0 and will lead to further work involving more tests for more clarifications and support.

Table 3. Correlation of All variables for Stakeholders

Variables	Knowledge	Skills	Assessment
Knowledge	1	.975**	.977**
Skills	.975**	1	.944**
Assessment	.977**	.944**	1
Individual & Future Perspective	.931**	.967**	.892**

Table 4. Q-Q plot of Knowledge, skills, Assessment and Future perspective for All Stakeholders



V. EVALUATION RESULTS & ANALYSIS

Involvment of doctors, DBA and visual designers play a vital role in assessment and future perspective evaluation of IV applications for multiple EHR. CARE 1.0 comprising of knowldege, skills, assessment and future perspective are already existing consitituent components within other models such as [28-33]. The relationship between these four components needs to justified based on feedback from multiple IV associated stakeholders.

Existences of a strong correlation observed between knowledge and skills that is .975 that provokes skills are positively correlated with knowledge and any increase in knowledge of stakeholders using IV applications will yield an increase in operating capabilities of the stakeholders. As mentioned in IV model CARE 1.0 the correlation values between knowledge versus assessment and future perspective are .977 and .931. These evidences, as values between the standard prescribed range of -1.90 to +1.90, thus represent an improvement in knowledge will yield positive on assessment and individual/future perspective for the stakeholders.

Skills have correlation values with assessment and future perspective as .944 and .967 respectively. This clearly shows that increase in skills will impact positively increase in assessment and future perspective. So as doctors will improve skills to operate IV applications this will yield better assessment and tendency for future perspective, understanding with respect to use and implementation in multiple EHR.

The assessment shows a linear relationship with individual perspective as correlation values lie within the range below than 1.90 that is .892. So that individual perspective is going to progress with the positive progress in assessment capabilities of doctors and other stakeholders with the use of IV tools in EHR at government hospitals. As previous research proved the existence of four components of CARE 1.0 knowledge, skills, assessment and future perspective [11].

Results are dictating based on Tables 3 and 4, increase in IV knowledge impacts positively not only on skills but assessment. In the same fashion, skill is making positive relation in direct relationship with assessment and future perspective with the use of IV applications in multiple EHR. This is also evaluating the concept of involvement of doctors, DBA and visual designers together. Though results for each study were calculated separately and that are showing similar range values in terms of correlation. Evaluation of all factors of all three studies proved a relationship between groups is associated in a similar way as that found in individual group of doctor, DBA and visual designers. These results not only can be used for proving hypotheses H1-H5 as mentioned in Fig. 1 but also analysed that each component is dependent positively in relation to each other thus having a strong bond.

VI. FUTURE WORK & LIMITATIONS

IV of multiple EHR fully supports the exploration of various health related events in patients based on user requirements. Complexity in understanding of data knowledge can be simplified by visual objects and simple queries for doctors based on input with other stakeholders. Occlusion of

important patient events and sequences in color codes usually restrict the list of contents based on functional limitation. Though in this paper, focus is given on feedback from different stakeholders, but involvement of different background medical staff such as nurses, attendants and technical IT staff will yield an improved version in oncoming applications. Though factors of assessment and future perspective are evaluated based on limited resources but an enhanced evaluation with a maximized number of participants and in varied environment will help in developing more efficient solutions with a number of factors based on availability of resources.

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