Examining the Role of IS Affordances in Enabling Time Critical Clinical Practices: An Information Processing Perspective

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Abstract

Globally, the healthcare domain is seeing quality improvements through the adoption of Information Technologies in its delivery, processes and culture. Healthcare quality is further refined as technology allows for knowledge dissemination, informing existing practices across countries with minimal effort. However, what affordance does the introduction of technology offer in a time critical environment? In this paper, we present an ongoing case study of a decision support system deployment at The Alfred Hospital, in Melbourne, Australia. This work outlines the affordances in: i) the time critical Trauma Centre from an information processing perspective, and ii) clinician use of the Algorithm Designer component to enrich the supported system processes. We observe how information standards, synergy and renewal were developed between the system and the users, to reduce error rates. We present a preliminary model of the important role Information Technology plays in the context of the Trauma Centre practices.

Keywords

Critical Clinical Practice, Healthcare, IS Affordances.

INTRODUCTION

The increase in expenditure and the desire to improve healthcare quality are driving the adoption and research of Information Technology (IT) in healthcare on a global scale (Braa et al. 2004; Goldschmidt 2005). The Global Health Observatory and the diagnostics and Laboratory Technology are key programmes in the World Health Organization that recognizes the key role health statistics and Information Systems (IS) play in contemporary healthcare practices. The Health Informatics Forum for instance is a network of over 28 health informatics associations and 3,500 practitioners from around the world that is generating robust discussions on the role of technology in supporting clinical practices. Whilst the implications of IT in healthcare are likely to be pervasive in the coming years, the challenge is to better understand how IT adoption in healthcare restructures the delivery system, reengineers care processes and recreates the culture in which healthcare occurs (Goldschmidt 2005).

One emergent area of research in this field is diagnostic pathways in time critical environments, a process supported through the use of clinical decision support systems (Berner 2007). The use of decision support systems in hospitals to enact clinical procedures and diagnostics is widely recognised but there is still a lack in understanding of how that is achieved or developed. This is important to better understand how decision-support technology can improve all types of healthcare decisions and transform health care (Goldschmidt 2005). In this study, we examine the application of information processing capabilities involving both computer hardware and software that deals with the storage, retrieval, and use of health care information, data, and knowledge for communication and decision making in a time critical environment.

The contributions of this research are twofold. We observe the impact of affordance on clinicians in our case study environment. To measure this impact, we study the preventable error rate in procedures. In addition to this, interviews are conducted toward determining user satisfaction and clinical efficacy. Beyond the impact afforded by introducing the IS, we regard the Algorithm Designer, a component of the IS that incorporates the clinician expertise in extending the processes supported by the IS. By affording growth in the IS knowledge base performed by the end users, the IS is able to evolve and incorporate contemporary medical practices and procedures.

HEALTH IS AND AFFORDANCES

Health IS include applications ranging from electronic health record, personal health record, decision-support and telemedicine systems (Goldschmidt 2005). These healthcare IS afford clinicians the ability to access patient data and medical history electronically and independent of institution or location. This allows for patient records to be entered into decision-support systems to inform pertinent healthcare decisions through the retrieval and use of healthcare information, data, and knowledge. A positive side effect of healthcare IS adoption in electronic record keeping is the affordance for information dissemination across medical facilities.

The concept of affordance arose primarily from the field of psychology (Gibson 1977) and draws on an ecological alternative to explain how inherent values and meanings of things in the environment can be directly perceived, and how this information can be linked to the action possibilities offered to the organism by the environment. The concept of affordances points to a special configuration of properties. When the apparent affordances of an artifact match its intended use, the artifact is easy to operate. When apparent affordances suggest different actions than those for which the object is designed, errors are common and signs are necessary (Gaver 1991). A number of formalizations on the concept of affordance have been advanced, notably around affordances are dispositional properties of the environment (Turvey 1992), affordances are properties of the animal-environment system (Stoffregen 2003), affordances are relations between the abilities of organisms and features of the environment (Chemero 2003). IT affordance focuses on the strengths and weaknesses of technologies with respect to the possibilities they offer the people that might use them. The use of affordances to analyze the design of technologies explicitly, help suggest ways to improve their usability (Gaver 1991).

IS affordances are defined as relationships between abilities of an individual and features of an information systems within the context of the environment in which they function (Chad 2011). According to Chad (2011), the concepts of an affordance range in a clinical environment and his study focuses on understanding the affordance threshold as theoretical constructs in the nomological network of affordances that help to explain the use of IS as a function of the difficulty of acting on IS affordances. The study seems to suggest that human variables in a clinical setting afford both predictable and unintended occurrences in IS use even amongst the most established and professional. This is in particular to IT-enabled solutions that simultaneously lead to new or improved capabilities, relationships and better use of assets and resources (i.e. enhanced capacity to act). Affordances and technology change are invariably linked; recognizing that IT is increasingly building on the knowledge and skills of professionals and day-to-day practices of sub-cultures. Henceforth, IS affordance celebrates the use of IT tools, the personal qualities of people and complex divergent networks to achieve its objectives.

AN INFORMATION PROCESSING VIEW

Information processing research posits that organizations and individuals need quality information, and the capability to gather, interpret, synthesize and disseminate information properly to cope with uncertainties (e.g. in technology, demand and supply) and improve decision making (Tushman et al. 1978). It includes information processing *need*, *capabilities* and the fit between the two to obtain desired outcomes (Premkumar et al. 2005). The literature around information processing focuses on (1) developing buffers to reduce the effect of uncertainty, and (2) implementing structural mechanisms and information processing capability to enhance the information flow and thereby reduce uncertainty. According to an Huang et al. (2014), information processing network and an organization’s control mechanisms are central to developing these information processing capabilities. The structure of an information processing network describes the patterns through which communication is expedited and information is processed (Ahuja et al. 1999). Information processing networks are dynamic network-based information processing structure which operates as a coordination mechanism (Kwon et al. 2007). Over time, continual exposure to a specific type of organizational structure will propel individuals toward proficiency in processing information and their ability and confidence to solve problems, through ongoing learning, in a manner consistent with this structure (Turner et al. 2012). In other words, structures direct or adapt the behavior of individuals by facilitating the individuals' ability to obtain and derive meaning from key information related to their work. This view of the individual interacting with system to achieve information processing capability is reflected in the theoretical construct described below.

Efficacy in IS focuses on individuals' abilities to competently use computers (computer self-efficacy) in determination of computer use (Compeau et al. 1995). Efficacy in general refers to the level of control wielded by the individual (e.g. the role of an expert) or communities (for example supervision of neighborhood children, maintaining public order, etc.). Collective efficacy is high in cohesive communities with mutual trust and is low in communities that are not cohesive and that do not have mutual trust. Hence, we refer *clinical efficacy* to competence and confidence in using technology to perform tasks like decision-making, planning, resource allocation and etc. in a community or clinical environment.

In summary, information processing is an appropriate perspective to study health care IS affordances, such that it focuses on the strengths and weakness of technology with respect to the ability of the people who use them.

RESEARCH METHOD AND DATA COLLECTION

For this study, we use a case study method to address our research question. The case research methodology is particularly appropriate for this study for a number of reasons. First, case research addresses 'how' research questions (Walsham 1995) whilst examining processes (Gephart 2004), and our research question delves into the role of IS affordances in enabling time critical clinical practices. Second, because we established that time critical clinical practices forms an inherently complex and multi-dimensional phenomenon, an objective approach to research is difficult (Koch et al. 2011), making it more appropriate to examine the phenomenon by interpreting the shared understanding of the relevant stakeholders (Klein et al. 1999), or clinicians in this case. Case selection is based on a number of criterions: (1) the case must be a widely recognised time critical clinical practice to fulfil our examination of activities per our earlier definitions. (2) the processes of the clinical practice must be reasonably complex for underlying mechanisms to be studied, which means that information processing networks and activities are cited and (3) the case study must present opportunities for ethnographic research of clinicians, to study their efficacy. Based on these criteria, we chose to examine the *Trauma Centre at The Alfred Hospital* – a site of a major computerized approach to trauma management– as our case study. We narrow the focus of our inquiry to three pertinent themes: (1) the structure and environment of the trauma centre, (2) the actions of clinicians and those of its technology partners, and (3) the development of time critical information processing capabilities achieved through health IS affordances. To this end, the authors conducted site visits to The Alfred Hospital, Melbourne. We conducted semi-structured interviews (Taylor et al. 1998) with doctors, nurses and other clinicians, software developers since 2011 and collected secondary data from various documents related to the project. Data collection is ongoing. We also drew on secondary data such as newspaper articles, hospital releases to triangulate our mappings. The events timeline, our interpretive account of the events that unfold and diagrammatic representations of our theoretical ideas were verified with our informants. If our findings appeared to extend beyond the propositions of the lens, or if propositions emerged that were unsupported by our empirical data, we conducted additional interviews to build an explanation iteratively (Walsham 2006). Ongoing data collection analysis will extract, confirm, and use pieces of evidence that illustrated the continual interplay between clinicians and the technology to inductively derive a practice model (Montealegre 2002; Newman et al. 1992).

There were forty-eight participants for this study, some of whom opted to not share their demographic information. The participants were volunteers from amongst The Alfred's trauma staff that had been rostered into trauma teams for each scenario. Deliberate effort was made to ensure volunteers would partake in at most two simulations of differing scenarios to obtain feedback from a wide range of trauma staff. Of the data acquired, there were twenty-three males and twenty-five females, of which one was aged 18-23, eight were aged 23-28, thirty-seven were aged 29-45, and two were aged above 46. Participants' expertise varied, with eight having experience in the trauma centre for less than a year, seventeen for 1-5 years, twelve for 6-10 years, and nine for 10+ years. Out of the forty-eight participants, six were TNL's (all female; all aged between 29-45), with two having experience in the trauma centre for less than a year, two for 1-5 years, and two for 6-10 years. Two had intermediate computer experience and four were novices. Similarly, out of the six TNLs, five were right handed and one was left handed.

We performed data analysis of secondary data concurrently during primary data collection to take full advantage of the flexibility of the case research approach. We used our theoretical understanding of health IS affordances and information processing as a guiding lens to examine the initial data. Our approach focuses on both coordination processes and coordination outcomes within trauma diagnostic and treatment context. Moving between the empirical data, our guiding lens and the related literature exposed new patterns and allowed us to develop further mappings of the coded responses. As part of our data analysis, we adopt a combination of the temporal bracketing, narrative, and visual mapping strategies to organise the empirical data (Langley 1999; Langley 2009).

CASE DESCRIPTION: TRAUMA RECEPTION AND RESUSCITATION AT THE ALFRED

The Trauma Centre at The Alfred Hospital in Melbourne, Australia, is the site of a major investigation into the value of a computerized and algorithmic approach to trauma management, the Trauma Reception and Resuscitation (TRR) Project. The objective of this project is to assist Trauma Teams by guiding diagnoses with precedents and to facilitate the review processes of procedures performed for compliance. Previous studies in Australia, Europe and the United States have demonstrated that methodical approaches drawn from other high-risk domains should be incorporated into healthcare practices to reduce preventable errors, patient harm and risk (The Joint Commission 2009), but there is some ambiguity in the results associated with measuring compliance with algorithms in real-time e.g. (Powner, Miller and Levine 2005). Therefore, a major aim of the TRR project is to establish a standardized environment. This aim allows for testing of whether compliance with evidence-based medical approaches will indeed improve outcomes in major trauma management with a measurable reduction in errors (Fitzgerald et al. 2011).

At the heart of the TRR Project is the TRR System that guides medical staff during the crucial first 30 minutes of trauma reception and resuscitation, as this time period has been observed to bear significant impact on preventable morbidity and mortality (Clarke and Spejewski et al. 2000, McDermott et al. 2007, Ivatury et al. 2008). Patient data including vital signs, confirmed and/or unconfirmed diagnoses and treatments are entered into the TRR System directly via a touch screen monitor by the Trauma Nurse Leader. Based on this data, computerized algorithms prompt the Trauma Team in real time to confirm the state of the patient, perform procedures and administer drugs as well as assisting with diagnosing injuries. The TRR System displays prompts and patient data on a large overhead 40” monitor mounted on the wall of the Trauma Bay to the Trauma Team. Compliance with the algorithms is guided by real-time computer generated prompts linked to real-time data collection. Computerized video audit was used to verify compliance and to assess error rates. The medical algorithms at the core of the TRR System serve to guide and support the Trauma Team. They are neither prescriptive nor do they replace the expertise of the medical staff. The algorithms have been, and will continue to be, subject to close scrutiny, discussion and evaluation by trauma specialists.

Successfully integrating a computer system into the specialized and highly pressured trauma care environment required close collaboration between the software developers at the S Innovation Lab (removed due to review process) and the medical staff at The Alfred. The other key stakeholders in the project consists of over 10 domestic and international hospitals, research institutes and trauma centers. The names of stakeholders and collaborating organizations are removed due to review process. They are available from the authors on request.

Initial usability testing was performed with the Trauma Nurse Leaders, who were the users that would be interacting with the touch screen input interface. This test was performed in a usability lab environment with eighteen participants – seventeen of whom where Trauma Nurse Leaders working at the Alfred and one lecturer who was involved in the development of the system, to refine the effectiveness and efficiency of the interface. The human variables introduced in a multidisciplinary team, coupled with fluctuating patient conditions, resist the modeling of a standardized environment. These human variables afford error occurrences even amongst established and experienced trauma centers and professionals. Parallel to flight control systems that support flight teams with real time error avoidance and feed-back, we developed a decision support system for trauma teams that allow the trauma team, or the Subject Matter Experts (SMEs), to enrich the system's pathways (Fitzgerald et al. 2011). The focus of this paper is the relationships and interaction between subject matter experts at The Alfred, Clinicians at the trauma centre and software developers in using the TRR System and developing user-centered algorithms. The result is an innovative feature of the system, the algorithm designer, which enables the medical staff themselves to create medical algorithms in an electronic form compatible with the system.

This algorithm designer supported enrichment process allows a trauma team to commune outside of a time critical environment to develop therapeutic and diagnostic courses of action based on patient conditions. The benefits of the algorithm designer include: 1) the removal of time pressure, 2) the absence of significant training required for the SMEs to enrich the system knowledge base, 3) affordance for a self-sustaining knowledge base available to professionals to be employed in review and training purposes, and 4) medical staff control over the reference data upon which the medical algorithms depend on.

PRELIMINARY FINDINGS: IS AFFORDANCES IN TRAUMA RECEPTION AND RESUSCITATION

This section presents preliminary findings from data analysis of largely interview notes and printed documents collected during preliminary data collection. The section focuses on three crucial phases of integrating the trauma reception and resuscitation system into its reference process. In the preparatory phase, we describe the semantic and physical affordances and impact to the medical staff at The Alfred Hospital and the developers when creating algorithms for a system. Secondly, in the diagnosis and treatment phase, we summarize the semantic and physical affordances and impact of implementing auxiliary systems for the process. Following that, we outline the semantic and physical affordances observed in the maintenance phase of the process. Physical affordances refer to the function of the software and facilities for the user to design, test and upload medical algorithms. Impact describes the application for the algorithm designer.

The Preparation Stage

The first thirty minutes of trauma reception and resuscitation bears a significant impact on patient outcomes, due to the often serious conditions patients arrive in (Kramer 2009). It falls to the prerogative of the trauma team to assess and determine therapeutic and diagnostic pathways from patient conditions. Correctly recognizing afflictions and dealing with them is critical as errors invite preventable morbidity and mortality. A 28 member multi-disciplinary medical team comprised of nurses, emergency physicians, anesthetists and trauma surgeons served as Subject Matter Experts (SME) in this phase. The SMEs were convened to acquire, collate and curate the most recently available and relevant evidence relating to trauma management. The SMEs took 9 months to construct the algorithms, which are categorized into Early Management of Severe Trauma (EMST) categories (Civil 1999). The SME team were provided with several guidelines for translating their recommendations into medical algorithms. For instance, the SME teams were provided instruction toward i) identifying key 'decision points' that require a response from the Trauma Team, ii) limiting the options, and iii) defining a reasonable time for task performance.

The process of converting medical procedures into computer-based algorithms created lively discussions among the medical staff. Fortunately some of the medical staff understood the constraints of binary logic and were able to assist in identifying the criteria needed for algorithm development. Trauma specialists added a timeline to best-practice algorithms to enable computerization and real-time prompts. Informal rapid prototyping involving close collaboration between developers and clients was a successful methodology for developing the Algorithm Designer and the Algorithm Tester.

The TRR algorithms represent an advance in medical algorithm design because a suggested time frame is allocated to each algorithm step. This enables the generation of real time prompts guiding trauma management. It also provides an evidence-based guide for time of intervention and duration of procedure. The algorithms cover the majority of presentations to The Alfred Hospital Trauma Centre. The majority of evidence used to inform the algorithms was clinical opinion or consensus based because the team found that well-established evidence to support trauma management was scarce. The algorithms that prompt trauma staff to perform actions based on the patient's vital signs, procedures performed, drugs administered and injuries diagnosed, are accompanied by written evidence published in a trauma manual.

Table 3. Affordances and Impact in Preparation Stage

Axial Themes	Representative Evidence/ Empirical Constructs
Semantic Affordances in Preparation	*"It was not easy for some trauma specialists to come to terms with the need to quantify physiological cut-off points to the extent required by this type of decision making."* [Perceived role of expert]
	"The timeline is an essential component of TRR medical algorithm design, The first 30 minutes of trauma reception and resuscitation is crucial" [Time critical nature]
IT-enabled Processing Capabilities	*"This information was translated into a set of algorithms in graphical format."* [Translation affordance]
	"The original algorithms were created using Microsoft Visio" [Modelling affordance]
Impact on Preparation	*"Some algorithms are triggered immediately after the patient arrives in the Trauma Bay."* [Advanced medical algorithm]

Diagnosis and Treatment

The algorithms, although created individually, are combined into a single file before being uploaded into the TRR System. The TRR System provides hospital trauma teams with access to computerized decision support for the first 30 minutes of trauma management. The system depends on evidence-based medical algorithms prepared and as explained earlier. When the TRR System is operating, it compares externally input data with reference data to generate the outputs, which include visual prompts suggesting diagnoses and treatments. Some algorithms are triggered immediately after the patient arrives in the Trauma Bay. Others are triggered by the input of patient data captured directly from the vital signs monitor or via manual input. Yet others are triggered by particular diagnoses, treatments, vital signs or particular combinations of these. Since the number of prompts on screen at any time is restricted to four, each prompt is allocated a level of urgency to ensure that medical staff are prompted to perform critical procedures before non-critical procedures. To successfully link the medical algorithms created by the clients with the TRR System, it was essential to enforce a standard format.

The TRR System in the Trauma Bay is set up with two screens. A large overhead screen enables the Trauma Team to view patient data and action prompts. A touch screen is managed by the Trauma Nurse Leader (TNL) who is responsible for monitoring automated data entry and for manual data entry. Preparation prompts appear on both the touch screen and the overhead screen to enable team members to carry out the necessary action(s) while communicating with the TNL who enters the data into the system. 'Vital signs check' prompts only appear on the touch screen because the data are usually captured from the vital signs monitor and readily accessible to the TNL who is in a position to confirm the accuracy.

Table 4. Affordances and Impact in Diagnosis and Treatment

Axial Themes	Representative Evidence/ Empirical Constructs
Semantic Affordances in Diagnosis	*"The medical staff had anticipated that their algorithms, created using Microsoft Visio, could be simply integrated into the TRR Software." "It soon became clear that a straightforward Visio to XML conversion was not adequate to achieve the degree of complexity required for full functionality of the medical algorithms"* [Perceived role of expert]
	stress is introduced from the experience, recollection and team coordination involved in the time pressurized initial period of receiving and resuscitating the patient (Fitzgerald et al. 2011) [Urgency of operations]
IT-enabled Processing Capabilities	*"When the Trauma Nurse Leader selects the prompt, a window appears requesting confirmation of the blood pressure reading. If the value is less than 100, the algorithm continues. "*[Detection affordance]
	"Depending on the Trauma Nurse Leader's responses to theses prompts, appropriate treatments may be suggested, other algorithms may be triggered and diagnoses may be suggested. At each stage the TNL may decline to follow the suggested treatment or diagnosis." [Diagnosis affordance]
Impact on Diagnosis	*"the input of patient data captured directly from the vital signs monitor or via manual input triggers visual prompts suggesting diagnoses and treatments"* [Accurate (to algorithm) diagnosis]

The Maintenance Stage

In practice, all the medical algorithms are subject to an ongoing process of evaluation and amendment. All parties in the project came to realize that a custom-built tool was needed to enable the medical staff to continue to create and maintain the algorithms themselves whenever new evidence becomes available and protocols or practices change. Several months into the design process a design tool was added to the client's software requirements. An alternative to providing a design tool to the clients was for the developers to code all the algorithms themselves. This option was rejected for both the period of system development and for system maintenance following deployment as being neither time efficient for the developers nor cost effective for the clients. The software developers had a constrained timeline for development and they realized that converting the medical algorithms, already created in Visio, into a format compatible with their custom-built software would take a considerable amount of their development time. Initially, the medical staff provided about a dozen algorithms, however this number was expected to increase over time. Some of the algorithms had a relatively simple logic structure, but others were complex, requiring medical knowledge to fully appreciate the structure.

The Algorithm Designer became a versatile tool that enables the clients to modify and update the TRR System after deployment. The Designer was developed simultaneously with, but separately from, the main TRR System. A rapid prototyping technique was used to build and successively modify the Designer during a close, informal collaboration between the developers and trauma specialists. This describes the development of the tools that enables trauma specialists to maintain the TRR System after its deployment. The Algorithm Designer and Algorithm Tester provide intuitive, easy-to-use interfaces enabling trained medical staff to translate medical algorithms into an electronic format compatible with the TRR System. They enable clinicians to both design and test medical algorithms. The Algorithm Designer serves two purposes – it allows the user to create and edit all medical reference data used by the system and, as the name suggests, it allows the user to design medical algorithms. The reference data consist of all treatments, diagnoses, injury mechanisms and other data used by the TRR System. The algorithms rely on the reference data to describe the various medical procedures which may need to be performed on a trauma patient. The application also performs numerous automated checks and displays appropriate warning and information dialogs as the user adds and removes symbols from the algorithm.

In view of the critical importance of algorithm accuracy to patient safety, it is essential that each algorithm be thoroughly tested before it is integrated into the TRR System. The Algorithm Tester incorporates the same algorithm processing engine component used by the TRR system to process algorithms and generate prompts. The Algorithm Tester is designed to test the operation of algorithms by accepting inputs (e.g. treatments, diagnoses and vital signs), process the logical flow of the algorithm nodes and output appropriate prompts for interaction with the user. The Tester simulates the operation of the algorithm as it would be in the live system and allows the designer to check the accuracy of all the prompts that will be generated in the live system. It enables the user to input test data and to confirm that the required action prompts appear at the specified times and with the specified urgency rating (high, medium or low). Once tested and considered to be satisfactory from the medical perspective, algorithms are saved and uploaded by the clinician into the TRR System.

Table 5. Affordances and Impact in Systems Maintenance Stage

Axial Themes	Representative Evidence/ Empirical Constructs
IT-enabled Processing Capabilities	*"The Algorithm Designer allows the user to create and edit all medical reference data"*[Edit Function]
	"The Algorithm Designer design medical algorithms"[Process Reengineer]

DISCUSSION AND CONTRIBUTION

The TRR System is designed to provide trauma teams with access to real-time best-practice in trauma management by providing decision-support software for the first 30 minutes of trauma management. One of the major factors contributing to the successful acceptance of the system was the provision of a facility for clinicians to create and maintain the medical algorithms on which the system is based. The Algorithm Designer is an auxiliary software tool that enables trauma specialists to adapt the system to meet their own particular needs. Using it clinicians can add, upgrade and delete the algorithms and the reference data upon which they are based. Close collaboration between developers and the clients combined with the rapid prototyping methodology for development of the software were critical factors in its successful implementation. Although initially there were minor problems resulting from giving the clients control over the maintenance of the medical algorithms, the benefits are overwhelming because the medical aspects of the deployed computer system are under the ongoing control of trauma specialists.

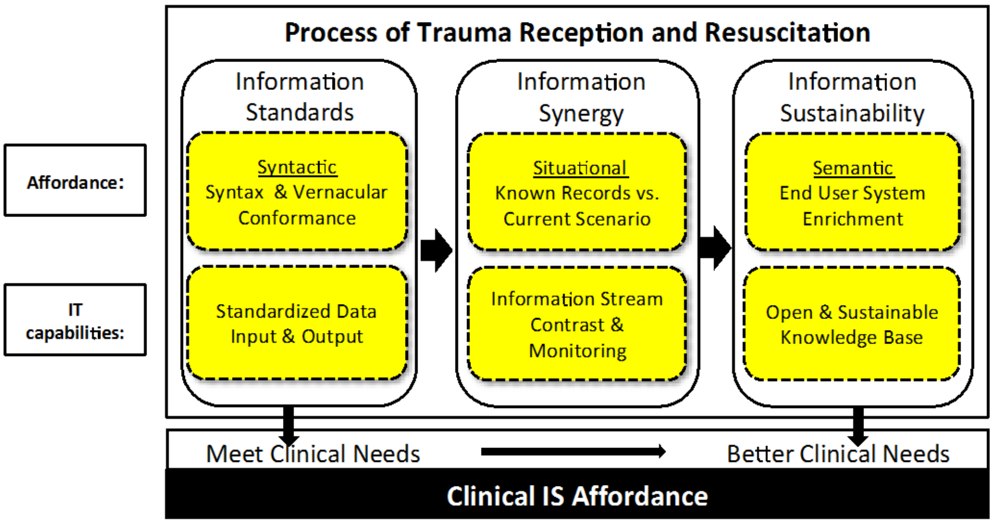

Figure 1: The Preliminary IS3 Model and how Clinical IS Affordance is offered

Development of Information Standards

The first step toward creating a standard environment for trauma management was to develop computerized medical algorithms. The main objectives of these algorithms are to identify and document standards for clinical trauma management derived from empirical evidence and 'best practice' trauma management approaches. In addition, the algorithms will afford error detection and measurement, where error is defined as deviation from the algorithms as applied in a standard physical environment. We observed that the errors of omissions were reduced by 21% (removed due to reviewing process) due to the establishment of standardized 'best practices'.

The Algorithm Designer is not only innovative for the purpose for which it was designed, it opens up possibilities for use in other medical settings. Using it, medical staff in a different environment can amend or replace the algorithms to meet their particular situations. For example, the algorithms designed by the trauma specialists at The Alfred Hospital deal with roughly 90% of all trauma cases treated at that hospital. Victims of gunshot wounds are rare. Hospitals in other parts of the world that encounter such wounds with higher frequency would be able to develop new algorithms to deal with these cases.

The Designer has the necessary flexibility to be adapted to any situation. The software also has great potential for use as a training tool for inexperienced trauma staff. In addition, standardization serves to bridge gaps in information localization and globalization, most notably, in conversions between imperial and metric systems when administering drugs. Another opportunity for standards is between vernaculars used in different countries, such as "O2 Sat" vs. "Oxygen Saturation" would reduce the delay for clarification or margin for error from misunderstandings. Through the data entry mechanisms in the Algorithm Designer, such discrepancies can be avoided by enforcing data input formats, whereas data output could still be displayed with localization to the region. This translates to a system module that guides user input so as to achieve standardised output that is understandable to all job roles in the trauma room. Side effect of this also ensures that if a well-established course of action is the standard response to specific patient conditions, the team can respond with their training immediately.

Development of Information Synergy

Informal rapid prototyping involving close collaboration between developers and clients was a successful methodology for developing the Algorithm Designer and the Algorithm Tester. Trauma specialists added a timeline to best-practice algorithms to enable computerization and real-time prompts.

The Algorithm Designer and the TRR System are not networked. Software developers are well aware of this issue. Although some problems arose when the main TRR System was not being developed concurrently with the Designer, the onus was on the user to ensure consistency between versions of the TRR System and the Designer. To overcome the potential problem of uploading mismatched algorithms and reference data into the TRR system, the same automated checks that are used by the algorithm designer to test the algorithms are performed whenever the TRR system is started, warning the user appropriately if mismatched algorithms and reference data condition is detected.

Data from sources such as monitoring equipment, patient records, and medical practices need to be processed, consolidated and reported by the IS. This relies on the natural synergy and pre/post conditions of patient vitals and history to determine appropriate procedures/course of actions. As the Algorithms developed are aggregated from precedent, algorithms displayed in the trauma bay give all members of the team access to experience in treating such wounds in real-time. This is in contrast to relying only on the recollection of the more experienced members in the team and the leadership in the bay. As patient history is incorporated in the Algorithms if available, conditions can be verified by the TRR prior to advocating a diagnostic pathway.

This Information Synergy however, relies on having Information Standards to afford opportunities for using algorithms developed by other hospitals. Compliance introduced by Information Standards and Synergy effectively allows the trauma clinicians to incorporate the collective and empirical experience of trauma clinicians to be used when assessing patient conditions to determine diagnostic pathways, something not possible prior to IT adoption.

Development of Information Sustainability

Auxiliary systems afford clinicians the ability to add, upgrade and delete the algorithms and the reference data upon which the algorithms are based. We term this, the continual capacity to manipulate and update reference data upon which the systems are built as the IT-enabled development of *information sustainability*. In our case study, the Algorithm Designer and tester are auxiliary software tools developed to afford trauma specialists management of medical algorithms using a custom-built graphical user interface. The tools can be easily adapted to different clinical environments. The Algorithm Designer and Algorithm Tester are innovative tools that provide trauma specialists with an effective way of maintaining the TRR System and keeping it at the cutting edge of medical knowledge.

In such a mission and time critical domain, the knowledge base of the system must adapt to the evolving needs of users, and hence, a means to enrich the system knowledge base needs to be provided. By allowing the end users who are also SMEs to enrich the knowledge base, the system can grow in afforded diagnostic pathways parallel to practitioner experience. This allows the system to conform to and incorporate contemporary medical practices. A non-proprietary input format reduces the barrier for entry to enrich and update the system knowledge base. Furthermore, it allows for practitioners both internal and external to the institution to reference the diagnostic pathways entered by clinicians well versed in their execution.

Information Sustainability requires Information Standards and Information Synergy to be applicable. Should compliance to standards not be met, and affordance for synergy not offered, the enrichment of system data cannot take place.

IMPLICATIONS AND ONGOING WORK

In this paper, we used an information processing perspective to observe IS opportunities and affordances in time critical clinical practices. For this, we present an ongoing case study of the Trauma and Resuscitation Project that occurred at the Trauma Centre of The Alfred Hospital, in Melbourne Australia. From the study, we observe the impact of affordance on clinicians in our case study environment and measure this impact using metrics of error rate and patient survival. In this study, we conducted interviews and secondary data collection discussing user satisfaction and clinical efficacy. Finally, we discuss the impact of the Algorithm Designer, a component of the IS that allows the clinicians to enrich and refine the processes supported by the IS. Based on analysis of preliminary and secondary data collected, the pragmatic results of the IS use reduced the errors made by emergency staff by over 20% (removed due to reviewing process). We also discuss the development of information standards, synergy and renewal pertaining to affordance of an IS tool that allows the SME to evolve the IS without having to engage software engineers. When used in conjunction with electronic patient history and records, the IS displays potential applicability as a teaching and training, as well as audits and reviews. In addition to this, the location independence of the system would be a step toward better knowledge consolidation and dissemination amongst clinicians. Data collection and analysis of interviews are still ongoing. As part of the requirements gathering process involved the study of recorded procedures, we are working toward future studies around adapting the IS in multi-national surgeon training and evaluations, and as a means to track and monitor procedures for accountability in cases of morbidity and mortality.

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