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Frameworks for Evaluating the Impact of Safety Technology Use

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The 2023 Global Ministerial Summit on Patient Safety declared "If it's not safe, it's not care," highlighting the crucial role of patient safety in healthcare. The Global Patient Safety Action Plan 2021–2030 of the World Health Organization (WHO) underscores the need for national policies and strategies for patient safety, surveillance, and learning systems for safety incidents, and improved healthcare practices, technologies, and medication use [1]. Recent technological advancements provide new opportunities for improving patient safety by standardizing and streamlining clinical workflows and reducing errors and costs by digitizing healthcare processes [2-4]. However, poorly designed or implemented technological approaches can instead actually increase the burden on clinicians, with alert fatigue and failure to respond to notifications by overworked clinicians leading to more medical errors [5-7]. Various frameworks, models, and methods have been developed to guide how to understand, design, and implement technology, and find a balance between the benefits and successful adoption by clinicians. This review evaluated the frameworks and models used to evaluate the impact of safety technology use and adoption through change management in acute care settings.

Multiple theoretical and conceptual models have been introduced and used in health informatics to understand and explore the relationship between clinicians and technology and also to evaluate and assure the impact and successful adoption of technology in practice. We identified several frameworks that were hybrid constructs of the technology acceptance model (TAM), theory of planned behavior and intrinsic motivation, hybrid theory of diffusion of innovation, sociotechnology analysis, organization theory, and health-organization-technology (HOT)-fit model. These frameworks are based on various theories such as those of planned behavior, reasoned action, sociotechnology, longitudinal acceptance, diffusion of innovation, organization, Bandura's social learning, and intrinsic motivation. Focusing on the frameworks and models used frequently for safety technology, we reviewed and compared seven frameworks and their constructors or concepts that affected the ultimate purpose of improving patient clinical outcomes and safety. We also added an introduction on the maturity models that are getting attention in practice.

1. TAM and Diffusion of Innovation

The TAM has been widely used as a framework for understanding how users adopt and use new technology [8]. It is rooted in the theories of planned behavior and reasoned action and posits that user intentions in using technology are based on perceived ease of use and usefulness. The TAM has been adapted to improve its accuracy by incorporating factors such as task relevance, personal, organizational, and social factors, intrinsic and extrinsic motivation, compatibility, attitude, and longitudinal usage. Another theory, diffusion of innovation [9], focuses on how new technologies are adopted and spread throughout communities and societies. The theory recognizes five adoption stages: knowledge, persuasion, decision, implementation, and confirmation. Different factors in each stage influence whether an individual or group will adopt the new technology, including perceived advantages and disadvantages, social norms and networks, and its complexity. Diffusion of innovation has been widely applied to understand the adoption and use of healthcare technologies, including Electronic Health Records (EHRs), telemedicine, and mobile health apps. Researchers have used this theory to identify barriers and facilitators to adoption and to develop strategies for promoting adoption and use.

2. UTAUT

The Unified Theory of Acceptance and Use of Technology (UTAUT) is another frequently used model in healthcare technology adoption [10]. It suggests that four key factors influence user intentions to adopt technology: performance expectancy (perceived usefulness), effort expectancy (perceived ease of use), social influence, and facilitating conditions. It also considers the moderating effects of gender, age, experience, and voluntariness of use. This theory has been applied to various healthcare technologies, such as clinical decision support systems (CDSSs), adverse-event e-Reporting, and mobile EHR apps, and has been found to be a useful framework for understanding technology adoption and use in healthcare settings.

3. SEIPS Model and DeLone and McLean Information Systems (D&M IS) Success Model

The System Engineering Initiative for Patient Safety (SEIPS) model is a systems-based framework for identifying healthcare factors contributing to patient safety incidents [11]. The model includes five main components: person, task, technology, organization, and environment. Person refers to the competencies, attitudes, and behaviors of individuals involved in the healthcare process. Task refers to the activities and workflows involved in the healthcare process. Technology includes the tools and equipment used in the process. Organization contains the policies, procedures, and culture of the healthcare organization. Environment designates the physical and social context in which the healthcare process occurs. The SEIPS model is useful for identifying potential sources of error and inefficiency in healthcare processes, and also for developing targeted interventions to improve patient safety.

The D&M IS success model provides more-comprehensive categories for introducing information systems into organizations, focusing on system, information, and service quality [12]. The extended version of D&M IS consists of six interrelated dimensions: system, information, service quality, use, user satisfaction, and net benefits. The model explains the construction of the systems according to information, system, and service quality influencing intention to use, or use of the systems and user satisfaction. The consequences of its use are noted through net benefits. A systematic review utilized both the SEIPS and D&M IS models to classify antecedents toward safety technology use [13].

Table 1. Summary of concepts found in seven theoretical frameworks for the safe use of health information technology

Framework	Person	Technology			Environment	Organization	Task	Net benefit
		System quality	Information quality	Service quality				
TAM	o	Information system			-	o	o	-
Diffusion of innovation	o	Technology			-	o	-	Perceived benefits
UTAUT	o	Technology			Social	-	-	Perceived benefits
SEIPS	o	Technology			Physical	o	o	Outcomes
D&M IS success model	o	o	o	o	-	-	-	o
HOT-fit model	o	o	o	o	-	o	-	o
Sociotechnical model	o	Hardware, software, computing infrastructure, human–computer interface			External rules, regulations, pressures	Policy, procedure	Workflow, communication	System measurement, monitoring

TAM: technology acceptance model, UTAUT: Unified Theory of Acceptance and Use of Technology, SEIPS: System Engineering Initiative for Patient Safety, D&M IS: DeLone and McLean information systems, HOT: health-organization-technology.

4. HOT-fit Model

The HOT-fit model is a comprehensive framework that integrates organizational and technological factors affecting the success of health information technology (HIT) implementation. It broadens the D&M IS success model by including organizational factors and the concept of "fit" from the IT-organization fit model, and identifies the human, technology, and organization domains and their interrelationships that affect HIT usage. This model emphasizes the importance of the alignment among these dimensions to achieve optimal outcomes. The HOT-fit model is useful for categorizing and identifying the causes of the consequences of HIT implementation in healthcare. A previous study used this model to identify the barriers and facilitators influencing medication-related CDSS acceptance [14].

5. Sociotechnical Model

The theoretical sociotechnical framework underscores the interdependence between workplace technology and social systems. It emphasizes the importance of aligning the technology, people, and organizational context to achieve effective performance and satisfaction. The model aims to optimize the interaction between the technical and social aspects of work systems so that they are mutually reinforcing and work in harmony. It has been applied to various industries, including healthcare, to identify the factors influencing the successful adoption and use of new technologies. By considering the broader organizational and social context and the technical aspects of the technology, the sociotechnical model provides a holistic approach to technology implementation and use.

The conceptual sociotechnical model of Sittig and Singh [15,16] broadens the sociotechnical model by emphasizing the need to consider the relationships among the social, technical, and organizational factors of HIT design, implementation, and use. It highlights the importance of considering the social and organizational context in which HIT is implemented, including the impact on workflow, communication, and the roles and responsibilities of healthcare providers. This model also emphasizes the need for ongoing HIT evaluation and adaptation to ensure that it aligns with the needs and goals of the healthcare organization and stakeholders.

We have presented a brief overview of seven conceptual frameworks commonly used to study patient safety technology use and adoption. MMs are frameworks that describe the level of maturity of an organization in utilizing information systems and its ability to continuously improve its processes [17]. The models differ from previously reviewed frameworks, but they are useful to understand and explain the differences between the technological and social contexts of each organization. Initially proposed as a straightforward tool for identifying areas of organization software processes that require improvements [18], maturity models have been developed for various domains, including healthcare, with focuses on healthcare services, informatics, electronic medical records, interoperability, and usability, such as the HIMSS Electronic Medical Record Adoption Model and the maturity model of WHO for digital health [19,20].

The seven frameworks examine the relationship between technology characteristics and the individual characteristics and behavioral intentions of using it, focusing on six main related concepts (Table 1). Researchers have been concerned about barriers to information technology implementation and adoption caused by the lack of theoretical frameworks in health informatics. Clinical informaticians can utilize this review to address these concerns. Ongoing rapid advances in patient safety technology make theoretical frameworks increasingly necessary for inductively or deductively guiding research and formulating research questions and research positions within existing frameworks.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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